1994

Ostracoda of the Latest Cretaceous and Earliest Tertiary of the Gulf Coastal Plain: Biostratigraphy, Paleoenvironments, and Systematics.

Kasana Pitakpaivan
Louisiana State University and Agricultural & Mechanical College

OSTRACODA OF THE LATEST CRETACEOUS AND EARLIEST TERTIARY OF THE GULF COASTAL PLAIN: BIOSTRATIGRAPHY, PALEOENVIRONMENTS, AND SYSTEMATICS

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Geology and Geophysics

by
Kasana Pitakpaivan
B.S., Chulalongkorn University, 1984
M.S., Texas A&I University, 1988
December 1994

UMI Number: 9524476

ACKNOWLEDGMENTS

I am grateful to my major advisor, Dr. Joseph E. Hazel, for proposing the research project and for valuable help during the study. My committee members, Dr. Gary R. Byerly, Dr. Barun K. Sen Gupta, Dr. Lui Chan, Dr. Charles McCabe and Dr. Richard H. Kesel, are also thanked for their assistance.

Acknowledgment also is made to the Donors of The Petroleum Research Fund, administered by the American Chemical society for the support of this research through grant 23114-AC8. I am also grateful for fellowship funds supplied by the Palynology Industrial Consortium and administered by the Department of Geology and Geophysics. The Elsevier Science Publishing Company is thanked for granting permission to use a published material in this dissertation. The Department of Mineral Resources, Thailand kindly provided a leave of absence to the writer while attending Louisiana State University.

To Dr. Norman F. Sohl of U.S Geological Survey, who recently passed away, goes my gratitude for providing his sample collection and valuable disscussions on the Upper Cretaceous stratigraphy of the Gulf Coast. Dr. Rosalie F. Maddocks, University of Houston is thanked for providing faunal slides from the Brazos River section, and positive criticism. Dr. James Pospichal, Florida State University is thanked for his assistance with the calcareous nannofossil work. I also wish to express my gratitude to Dr. Virgil E. Barnes, Bureau of Economic Geology, University of Texas at Austin for valuable discussions of microtektites and his continuous encouragement. Dr. Byerly is also acknowledged for his assistance with the scanning electron microscope.

Special thanks are particularly due to my husband, Chekchanok Soonthornsaratul, for his helpful discussions, encouragement and support. To my father, Kaset Pitakpaivan whose own career in geology inspired me to seek a carrer in the earth sciences, goes my deepest gratitude for his encouragement and moral support.

TABLE OF CONTENTS

Acknowledgments		ii
List of Tables		iv
List of Figures		v
Abstract		vii
Chapter I	Introduction	1
Chapter II	Ostracodes and Chronostratigraphic Position of the Upper Cretaceous Arkadelphia Formation of Arkansas	10
Chapter III	Pseudomorphs of Spherules from a Cretaceous–Tertiary Boundary Section at Shell Creek, Alabama	40
Chapter IV	Ostracoda of the Haustator bilira Assemblage Zone (Maastrichtian) of the Eastern Gulf Coastal Plain: Application to Biostratigraphical and Paleoenvironmental Interpretation	54
Chapter V	Ostracoda of Cretaceous–Tertiary Contact Sections in Alabama and Mississippi	94
Chapter VI	Conclusions	139
Appendix I	Plates	144
Appendix II	Systematic Paleontology	167
Appendix III	Sample Localities and Stratigraphic Positions	181
Appendix IV	Relative Abundance Data of Ostracode Species	186
Appendix V	Letters of Permission	236
Vita		239

LIST OF TABLES

1	Sample localities	16
2	Abundance of ostracode species of the Arkadelphia Formation	17
3	Distribution of ostracode species in each sample from the Arkadelphia Formation	18
4	Relative abundance of ostracode genera	63
5	Relative abundance of ostracode species	64
6	List of five groups of ostracode species according to their difference in abundances in certain lithofacies	71
7	List of three groups of ostracode genera according to their difference in abundances in certain lithofacies	72
8	Summary of the cluster analysis of samples (Q-mode)	74
9	Full names of ostracode species that were abbreviated in the cluster analysis	76
10	Summary of the cluster analysis of ostracode species (R-mode)	78
11	A list of the sample constancy (C) and biofacies fidelity (BF) of species used in the cluster analyses	79
12	List of known ecological distribution of ostracode genera of the uppermost Maastrichtian deposits	87
13	List of samples	109
14	Relative abundance of ostracode species of the Cretaceous-Tertiary boundary section at Braggs roadcut location	111
15	Relative abundance of ostracode species of the Cretaceous-Tertiary boundary section at Shell Creek location	121
16	Relative abundance of ostracode species of the Cretaceous-Tertiary boundary section at Lynn Creek location	126
17	List of species that were found to disappear at the Cretaceous-Tertiary boundary	131
18	A list of Upper Cretaceous ostracodes found in the basal Tertiary unit of this study in comparison with those in the sections of east Texas	134

LIST OF FIGURES

1	Generalized distribution of Upper Cretaceous outcrops	3
2	Diagram illustrating the stratigraphic relationships of lithostratigraphic units of the East Gulf Coastal Plain	6
3	Location map showing sample localities	12
4	Scanning electron photomicrographs of the ostracode species Alatacythere aff. A. serrata, Antibythocypris gooberi, Antibythocypris macropora, Argilloecia sp., Ascetoleberis hazardi, Bairdoppilata pondera and Brachycythere foraminosa	24
5	Scanning electron photomicrographs of the ostracode species Brachycythere ledaforma, Brachycythere ovata, Brachycythere rhomboidalis, Curfsina communis, Platycosta lixula, Cytheromorpha arbenzi, Cytheromorpha sp., and Cytheropteron castorensis	26
6	Scanning electron photomicrographs of the ostracode species Cytheropteron navarroense, Aversovalva fossata, Cytherura cretacea, Escharacytheridea magnamandibulata, Escharacytheridea micropunctata, Eucythere sohli, and Fissocarinocythere huntensis	28
7	Scanning electron photomicrographs of the ostracode species Fissocarinocythere huntensis , Haplocytheridea bruceclarki, Haplocytheridea aff. H. everetti, Haplocytheridea renfroensis, Krithe whitecliffsensis, Loxoconcha clinocosta, Loxoconcha cretacea, and Orthonotacythere hannai	30
8	Scanning electron photomicrographs of the ostracode species Paracypris sp., Pterygocythere saratogana, Veenia adkinsi, Veenia arachoides, Veenia parallelopora, and Xestoleberis sp.	32
9	A summary chart covering the chronostratigraphic interval of the Platycosta lixula and Veenia parallelopara Zones	34
10	The location of the Shell Creek section, other Cretaceous-Tertiary boundary sections where spherules have been reported, and the proposed impact site, the Chicxulub feature	43
11	Upper Cretaceous and lower Paleocene section at Shell Creek	44
12	Photomicrographs of the pseudomorphs	47
13	Morphology and size distribution of the tektite pseudomorphs	49
14	Polished section photomicrographs of the pseudomorphs	49
15	Reconstruction of the relationships of the upper Maastrichtian lithofacies units of the eastern Gulf Coastal Plain	57
16	Stratigraphic and geographic position of samples used in this study	62

17 A dendrogram based on a cluster analysis of samples 73

18 R-mode dendrogram for species of ostracodes occurring in samples from the Upper Cretaceous Prairie Bluff, Providence, Owl Creek and Chiwapa of eastern Alabama to northeastern Mississippi 75

19 Distribution of ostracode species in the uppermost Maastrichtian deposits of the eastern Gulf Coastal Plain 81

20 Distribution of ostracode genera in the uppermost Maastrichtian deposits of the eastern Gulf Coastal Plain 82

21 Stratigraphic and geographic position of Veenia parallelopora, Veenia adkinsi and Veenia arachoides 85

22 Stratigraphic and geographic position of Brachycythere foraminosa s.l., Platycosta lixula and Fissocarinocythere pidgeoni 86

23 Location map of the Cretaceous-Tertiary boundary sections 98

24 The Cretaceous-Tertiary section at Braggs 99

25 The Cretaceous-Tertiary section at Shell Creek 100

26 The Cretaceous-Tertiary section at Lynn Creek 101

27 A trend curve of the number of species (S) and species diversity (H) at the Braggs section 117

28 The relative abundance of Upper Cretaceous species, incoming species and Brachycythere ovata (transitional form) across the Cretaceous-Tertiary boundary at Braggs 118

29 A trend curve of the number of species (S) and species diversity (H) at the Shell Creek section 123

30 The relative abundance of Upper Cretaceous species and Brachycythere ovata (transitional form) across the Cretaceous-Tertiary boundary at Shell Creek section 123

31 A trend curve of the number of species (S) and species diversity (H) at the Lynn Creek section 128

32 The relative abundance of Upper Cretaceous species, incoming species and Brachycythere ovata (transitional form) across the Cretaceous-Tertiary boundary at Lynn Creek section 128

ABSTRACT

Examination of the Ostracoda of the latest Cretaceous and earliest Tertiary of the Gulf Coastal Plain indicates that this microscopic crustacean is a practical, valuable tool for biostratigraphy and paleoenvironmental interpretation in this major geologic and geographic province. The newly established Veenia parallelopora Zone, an ostracode interval zone for the late Maastrichtian, allows correlation of the uppermost Cretaceous units across the Gulf Coastal Province. Veenia parallelopora, Brachycythere foraminosa, and Veenia adkinsi are characteristic species of this zone. The uppermost, latest Maastrichtian, part of this zone can be recognized by the presence of these three species plus Antibythocypris johnsoni, Brachycythere ovata (transitional form), Eucytherura reticulata, Opimocythere aff. O. hazeli, and Pectocythere hughesi. Many of the Upper Cretaceous ostracode taxa found in the Gulf Coastal Province seem to occupy the same or similar habitats as their present-day representatives. High percentages of species of one group of genera can be interpreted to indicate proximity to the coast. Whereas another distinctive group indicates deposits laid down in middle to outer shelf environments.

The study of the Cretaceous-Tertiary boundary sections at Braggs, Shell Creek and Lynn Creek reveals that many long-range, widely-distributed ostracode species suddenly disappeared at the end of the Cretaceous. However, no general decline in the species diversity is observed in the later part of the Cretaceous. The Cretaceous-Tertiary boundary can be recognized by the disappearance of many Cretaceous ostracodes species. The boundary at Braggs, where the Cretaceous part of the section is the most complete, is at the contact of the Clayton Formation with the Prairie Bluff. At Shell Creek and Lynn Creek the uppermost part of the Prairie Bluff is missing. Here a sand unit, the Clayton sand, is present between the Prairie Bluff and the marls of the Pine Barren Member of the Clayton. The lower part of this sand contains pseudomorphs of microspherules, interpreted to represent extraterrestrial impact ejecta. At least the lower part of the sand

containing the microspherule pseudomorphs correlates with the Cretaceous-Tertiary boundary clay in the stratotype at El Kef, Tunisia.

CHAPTER I

INTRODUCTION

This dissertation was initiated to study the ostracodes of the latest Cretaceous and earliest Tertiary of the Gulf Coastal Plain. This particular interval has received considerable attention because many groups of earth's biota suffered extinctions during this interval of time, and the possible causes of the extinctions, including the possibility of an extraterrestrial impact (Alvarez and others, 1980; Alvarez and others, 1984), are the subject of geological controversy. For the past decade the impact hypothesis championed by the Alvarez group at the University of California, Berkeley, and their followers has stimulated extensive worldwide research on this interval. However, before the actual causes of the mass extinctions and the true scenario of the Cretaceous-Tertiary boundary events can be determined, many more localities that are less well known and less studied should be investigated. These have the potential of making a major impact on the controversy. Localities in the Gulf Coastal Plain are among some of the localities that could make a contribution.

The main objective of this dissertation was to determine the stratigraphic and geographic distribution of the ostracodes of a 4.5 my time slice from about 70.5 ma to about 64.8 ma that includes the outcropping later Cretaceous and earliest Tertiary deposits from western Georgia to southwestern Arkansas. The uppermost Cretaceous lithostratigraphic units of this interval are the Providence Formation of Georgia and Alabama, the Prairie Bluff Formation of Alabama and Mississippi, the Owl Creek Formation of Mississippi, and the Arkadelphia Formation of Arkansas (Figure 1). The Clayton Formation, which was studied only in the Alabama/Mississippi area, is the lowermost Tertiary that is addressed.

Sources of study materials are 1) USGS collections taken from the interval of interest during the study of the molluscan Haustator bilira Assemblage Zone (Sohl, 1977; Sohl and Koch, 1986), 2) collections from measured sections of the Prairie Bluff and Clayton Formations in Alabama and Mississippi, 3) collections that exist in the H.V. Howe Microfossil collection and in the J.E. Hazel personal collection at Louisiana State

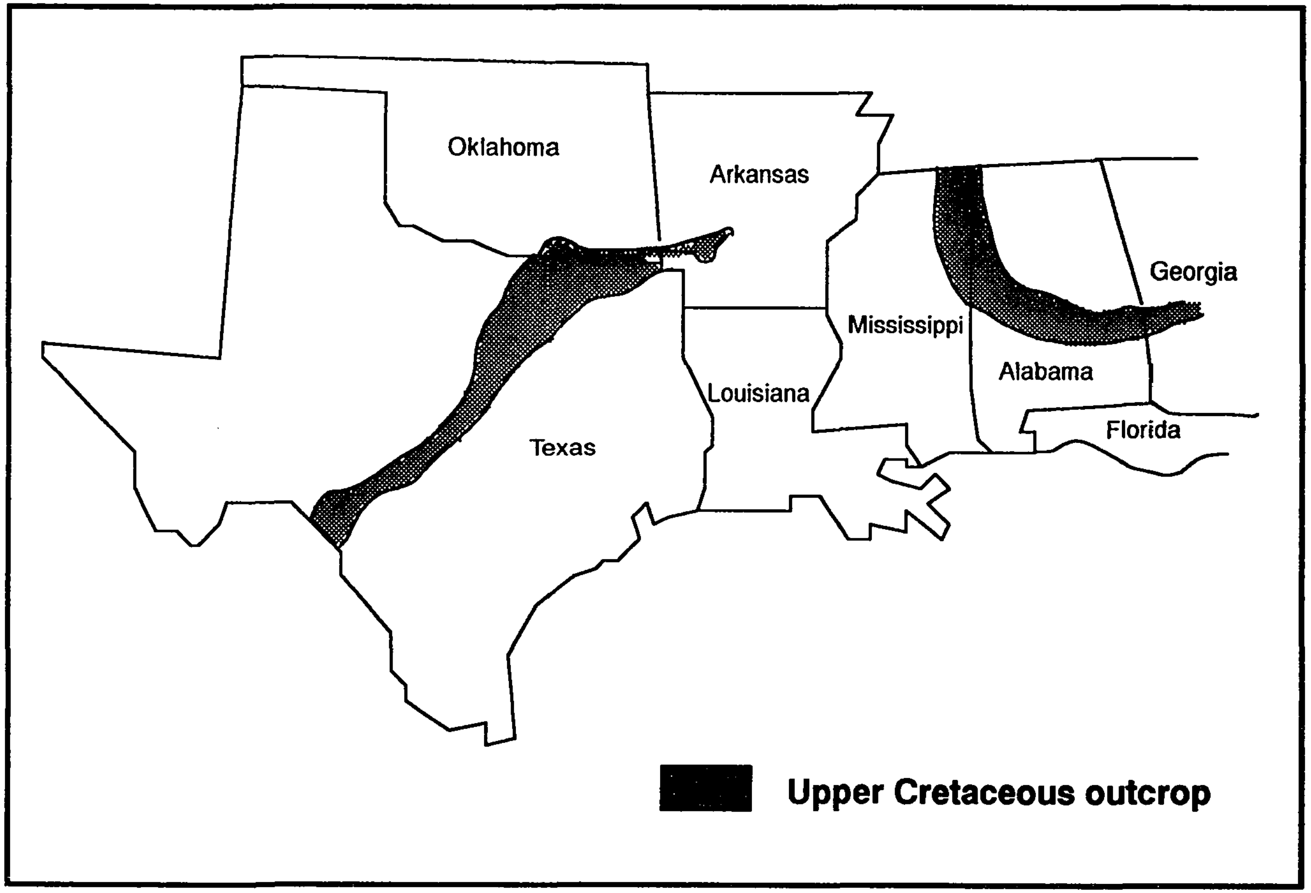


Figure 1 Generalized distribution of Upper Cretaceous outcrops.

University, 4) samples from the Deaderick Collection (see Henbest, 1946) of the National Museum of Natural History, Washington, D.C., and 5) collections used in an unpublished dissertation at Louisiana State University (Drouant, 1959).

The early phase of the research began with a study of the Arkadelphia Formation as a preliminary investigation to evaluate the possibility of dividing the ostracode Platycosta lixula Zone of Hazel and Brouwers (1982). This zone is the youngest and longest of the seven zones that were defined by Hazel and Brouwers (1982) for the Coniacian through Maastrichtian (Austinian-Navarroan) of the Atlantic and Gulf Coastal Geological Province. The results of this work are given in Chapter 2. The newly proposed ostracode interval zone, the Veenia parallelopora Zone, divided the Platycosta lixula Zone (Pitakpaivan and Hazel, 1994) and provided a fundamental biostratigraphic framework for the rest of the study.

The next phase included an extensive study of the uppermost Cretaceous units and the Cretaceous-Tertiary boundary sections in Alabama and Mississippi during which peculiar microscopic objects were found unexpectedly in the basal Clayton sand in Alabama. This serendipitous find resulted in a short contribution in Chapter 3 (Pitakpaivan and Hazel, 1992; Pitakpaivan and others, 1994). Further examination of the objects suggested that they are the pseudomorphs of microspherules that have been hypothesized to be the fallout products of an extraterrestrial impact on what is now the Yucatan Peninsula of Mexico at the end of the Cretaceous (Hildebrand and others, 1991; Smit and others, 1992). As a consequence, others scientists (Habib, 1994; Smit and others, 1994; Savrda, 1993) have begun to reexamine the less well known Gulf Coastal Plain Cretaceous-Tertiary boundary outcrops for further evidence to either support or dispute the impact hypothesis. The results of ostracode analyses from the Cretaceous-Tertiary boundary sections of this study are in Chapter 5.

The distribution of ostracodes in the uppermost Cretaceous of the East Gulf Coastal Plain are discussed in Chapter 4. Since ostracodes, a microscopic crustacean, have a benthic mode of life, they are useful as a biostratigraphic tool only within major zoogeographic provinces. Their biostratigraphic value is also limited by facies and paleoenvironmental control. However, with adequate understanding of their paleoecology and paleobiogeography, ostracodes have been shown to be a reliable stratigraphic tool by many authors. Therefore, the uppermost Cretaceous units of the Gulf Coastal Province of North America were selected as a testing device to gain a knowledge of ostracode paleoecology and paleobiogeography, as well as to determine their biostratigraphic utility in the region.

The lithostratigraphic units studied consist of the shallow shelfal clastic deposits of the Providence Formation in western Georgia and eastern Alabama, which grade into the shelfal calcareous mud deposits of the Prairie Bluff Formation in central Alabama. The calcareous muds, which have been called "chalks", extend from central Alabama to northeast Mississippi where they become more argillaceous and grade into the clastic units of the Owl Creek Formation (Figure 2). The Providence Formation (middle to upper Maastrichtian) and its coeval westward equivalents, the Prairie Bluff and the Owl Creek Formations are biostratigraphically entirely within the molluscan Haustator bilira Assemblage Zone (Sohl and Koch, 1986; Donovan, 1986). They were deposited during the last episode of Cretaceous transgression along a tectonically stable, trailing continental plate margin (Sohl and others, 1991). These units rest disconformably upon the Ripley Formation, and are in turn disconformably overlain by the Paleocene Clayton Formation.

Historically, the Cretaceous-Tertiary boundary in this region has been considered to be represented by a major hiatus resulting from a regression at the end of Cretaceous (Stephenson and Monroe, 1938). Some recent workers have continued this by concluding that the youngest Cretaceous deposits, as based on planktonic foraminifers, are middle Maastrichtian (for example, Smith and Mancini, 1983; Mancini and others, 1989) and that no late Maastrichtian exists in the outcrop of the Gulf Coastal Plain. However, other recent workers have pointed out that there is late and even the very late

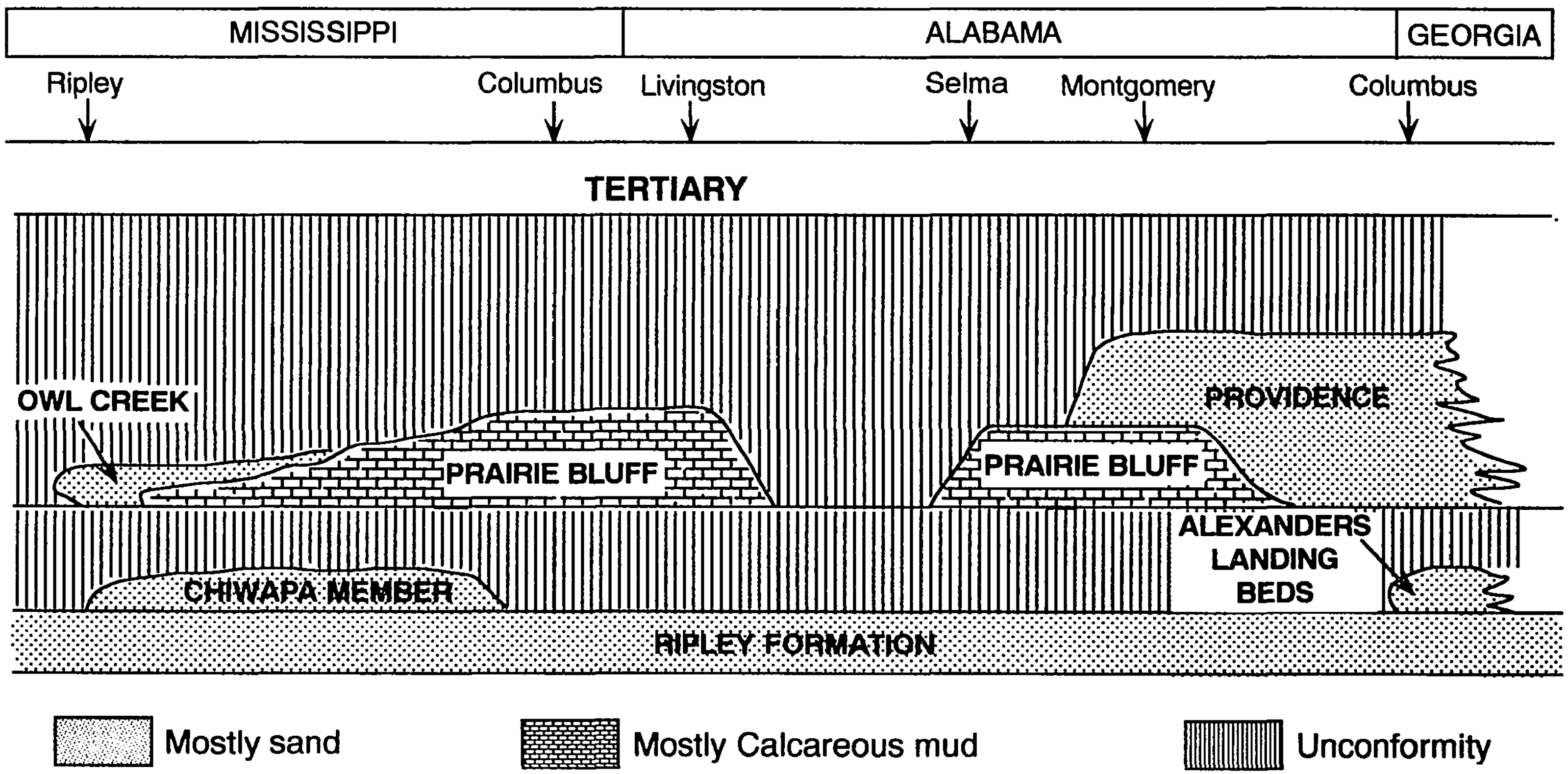


Figure 2 Diagram illustrating the stratigraphic relationships of lithostratigraphic units of the East Gulf Coastal Plain (modified from Sohl and Koch, 1983). Relative thickness expressed by vertical extent. Temporal relationship not implied.

Maastrichtian present (Habib and others, 1992; Moshkovitz and Habib, 1993; Olsson and Lui, 1993; Habib, 1994; Pitakpaivan and Hazel, 1994). The first two references cited point out that the last Cretaceous calcareous nannofossil zone, the Micula prinsii Zone, is present, at least in Alabama.

Chapter 5 discusses the nature of the Cretaceous-Tertiary contact interval deposits in Alabama and Mississippi and their ostracode assemblages. With the recently established ostracode zone for the uppermost Cretaceous (Chapter 2) and with the understanding of ostracode distribution across the region (Chapter 4), ostracodes can be reliably and successfully utilized to contribute to a better understanding of the Cretaceous-Tertiary boundary problem. Finally, in Chapter 6, the conclusions and a discussion of the research are presented.

For this study, a total of 158 collections were examined. Information on their geographic and stratigraphic distribution are given in Appendix 3. More than sixty two thousand valves of ostracodes were examined. Appendix 2 discusses aspects of the systematic paleontology of the ostracode assemblages. Appendix 4 lists the relative abundance of ostracode species.

REFERENCES TO CHAPTER I

Alvarez, L. W., Alvarez, W., Asaro, F. and Michel, H. V., 1980, Extraterrestrial cause for the Cretaceous-Tertiary extinction: Science, 208, 1095-1108.

Alvarez, W., Kauffman, E. G., Surlyk, F., Alvarez, L. W., Asaro, F. and Michel, H. V., 1984, Impact theory of mass extinctions and the invertebrate fossil record: Science, 223, 1135-1141.

Donovan, A. D., 1986, Sedimentology of the Providence Formation: *in* Reinhardt, J., eds., Stratigraphy and sedimentology of continental, nearshore, and marine Cretaceous sediments of the eastern Gulf Coastal Plain: Society of Economic Paleontologists and Mineralogists Annual Meeting Field Trip #3: 29-44.

Drouant, R. G., 1959, Stratigraphy and ostracoda of the Exogyra costata Zone of southwestern Arkansas: Unpublished Ph.D. dissertation, Louisiana State University, Baton Rouge, 158 p.

Habib, D., 1994, Biostratigraphic evidence of the KT boundary in the eastern Gulf Coastal Plain, north of the Chicxulub crator: New developments regarding the K/T event and other catastrophes in earth history, Houston, Texas, Lunar and Planetary Institute, 45-46

Habib, D., Moshkovitz, S. and Kramer, C., 1992, Dinoflagellate and calcareous nannofossil response to sea-level change in Cretaceous-Tertiary boundary sections: Geology, 20(2), 165-168.

Hazel, J. E. and Brouwers, E. M., 1982, Biostratigraphic and chronostratigraphic distribution of ostracodes in the Coniacian–Maastrichtian (Austinian–Navarroan) in the Atlantic and Gulf Coastal Province: *in* Maddocks, R. F., eds., Texas Ostracoda: Department of Geosciences, University of Houston, Houston, 166–198.

Henbest, L. G., 1946, Deaderick Collection of Foraminifera: Journal of Paleontology, 20, 517–518.

Hildebrand, A. R., Penfield, G. T., Kring, D. A., Pilkington, M., Camargo Z., A., Jacobsen, S. B. and Boynton, W. V., 1991, Chicxulub crater: A possible Cretaceous/Tertiary boundary impact crater on the Yucatán Peninsula, Mexico: Geology, 19, 867-871.

Mancini, E. A., Tew, B. H. and Smith, C. C., 1989, Cretaceous-Tertiary contact, Mississippi and Alabama: Journal of Foraminiferal Research, 19, 93-104.

Moshkovitz, S. and Habib, D., 1993, Calcareous nannofossil and dinoflagellate stratigraphy of the Cretaceous-Tertiary boundary, Alabama and Georgia: micropaleontology, 39(2), 167-191.

Olsson, R. K. and Lui, C., 1993, Controversies on the Placement of Cretaceous-Paleogene Boundary and the K/P Mass Extinction of Planktonic Foraminifera: Palaios, 8, 127-139.

Pitakpaivan, K., Byerly, G. R. and Hazel, J. E., 1994, Pseudomorphs of impact spherules from a Cretaceous-Tertiary boundary section at Shell Creek, Alabama: Earth and Planetary Science Letters, 124(1-4), 49-56.

Pitakpaivan, K. and Hazel, J. E., 1992, Pseudomorphs of Microtektites at the Cretaceous/Tertiary Boundary in Alabama and Mississippi: Geological Society of America Abstracts with Programs, 24(7), A361.

Pitakpaivan, K. and Hazel, J. E., 1994, Ostracodes and Chronostratigraphic position of the Upper Cretaceous Arkadelphia Formation of Arkansas: Journal of Paleontology, 68(1), 111-122.

Savrda, C. E., 1993, Ichnosedimentologic evidence for a noncatastrophic origin of Cretaceous-Tertiary boundary sands in Alabama: Geology, 21, 1075-1078.

Smit, J., Montanari, A., et al., 1992, Tektite-bearing, deep-water clastic unit at the Cretaceous-Tertiary boundary in northeastern Mexico: Geology, 20, 99-103.

Smit, J., Roep, T. B., Alvarez, W., Claeys, P., Montanari, S. and Grajales, M., 1994, Impact-tsunami-generated clastic beds at the KT boundary of the gulf Coastal Plain: a synthesis of old and new outcrops: New developments regarding the K/T event and other catastrophes in earth history, Houston, Texas, Lunar and Planetary Institute, 117-119

Smith, C. C. and Mancini, E. E., 1983, Calcareous Nannofossil and Planktonic Foraminiferal Biostratigraphy: *in* Russell, E. E., Keady, D. M., Mancini, E. E. and Smith, C. C., eds., Upper Cretaceous Lithostratigraphy and Biostratigraphy in Northeast Mississippi, Southwest Alabama, and Northwest Alabama, Shelf Chalks and Clastics: Field Trip Guidebook for 1983 Spring Field Trip of Gulf Coast Section, Society of Economic Paleontologists and Mineralogists, 16-28.

Sohl, N. F., 1977, Utility of gastropods in biostratigraphy: *in* Kauffman, E. G. and Hazel, J. E., eds., Concepts and methods of biostratigraphy: Downden, Hutchinson and Ross, Inc, Stroudsburg, Pennsylvania, 519–540.

Sohl, N. F. and Koch, C., 1986, Molluscan biostratigraphy and biofacies of the Huastator bilira assemblage zone (Maastrichtian) of the East Gulf Coastal Plain: *in* Reinhardt, J., eds., Stratigraphy and sedimentology of continental, nearshore, and marine Cretaceous sediments of the Eastern Gulf Coastal Plain, Field Trip No. 3: Society of Economic Paleontologists and Mineralogists, Annual Meeting, 45-56.

Sohl, N. F., Martínez R., E., Salmerón-Ureña, P. and Soto-Jaramillo, F., 1991, Upper Cretaceous: *in* Salvador, A., eds., The Gulf of Mexico Basin: The Geological Society of America Inc., Boulder, CO, 205-244.

Stephenson, L. W. and Monroe, W. H., 1938, Stratigraphy of Upper Cretaceous Series in Mississippi and Alabama: The American Association of Petroleum Geologists Bulletin, 22(12), 1639-1657.

CHAPTER II

OSTRACODES AND CHRONOSTRATIGRAPHIC POSITION OF THE UPPER CRETACEOUS ARKADELPHIA FORMATION OF ARKANSAS

(Published as article: Pitakpaivan, K. and Hazel, J. E., 1994, Ostracodes and chronostratigraphic position of the Upper Cretaceous Arkadelphia Formation of Arkansas: Journal of Paleontology, 68, 111-122. Reproduced here with permission from the editor.)

INTRODUCTION

An interval zonation consisting of seven zones based on ostracodes for the Coniacian through Maastrichtian (Austinian–Navarroan) of the Atlantic and Gulf Coastal Geological Province was defined by Hazel and Brouwers (1982). The youngest of these, the Maastrichtian "Cythereis" lixula Zone (the nominate species is now thought to belong to Platycosta Holden, 1964), is the longest in duration (about 6.0 my). This atypically long zone provides an indication that the younger Cretaceous ostracode assemblages were the least well known at the time of the Hazel and Brouwers publication. Further, the correlation of the ostracode events to planktic and lithostratigraphic events in the Maastrichtian of the Coastal Province by Hazel and Brouwers (1982) have needed revision based on additional information.

We have undertaken a study of the Arkadelphia Formation of Arkansas in order to investigate the feasibility of dividing the Platycosta lixula Zone, and to identify and illustrate the Arkadelphia assemblage using scanning electron microscopy.

This work forms part of a broader study of the latest Cretaceous and earliest Tertiary of the Gulf Coast by one of us (KP), which will be used as a Ph.D dissertation.

STRATIGRAPHIC SETTING

Arkadelphia was first used in a stratigraphic sense by Hill (1888, p. 53) when he applied the name Arkadelphia shales to "alternating blue clay and yellow sands" exposed in the vicinity of Arkadelphia, Clark County, Arkansas (Figure 3). The Arkadelphia shales were believed by Hill (1888) to be Tertiary in age, but later were later established by Harris (1894) on the basis of macroinvertebrate fossils to be of Cretaceous age. Veatch (1926, p. 28) recognized good outcrops of "the dark, laminated clays which overlie the Nacatoch sand" near Fulton, Hope, and Emmet, Arkansas, to which he applied the name Arkadelphia clay. The name Arkadelphia clay was subsequently replaced by the name Arkadelphia marl because marl represents the basic lithology of the

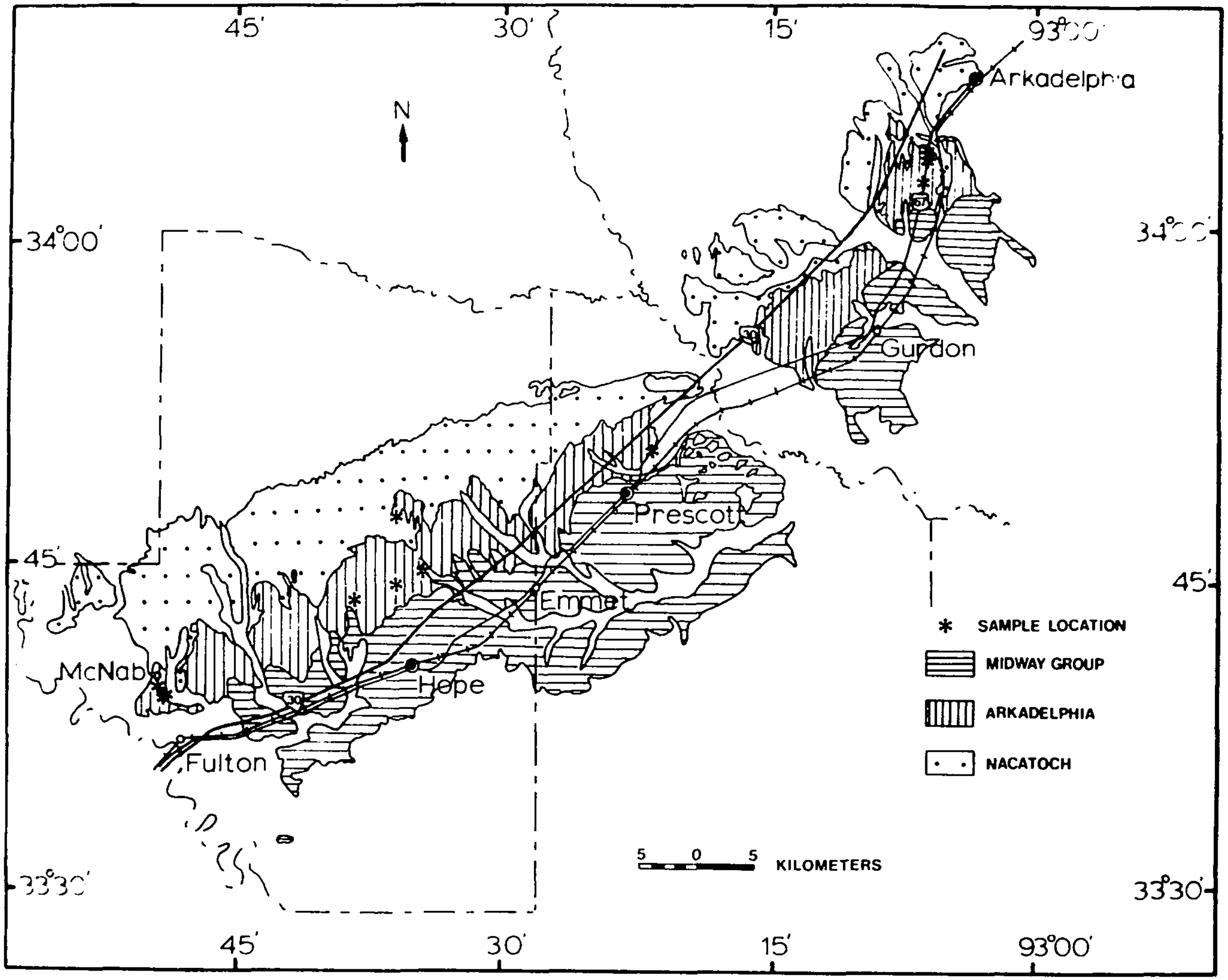


Figure 3 Location map showing sample localities. Map modified from Haley et al. (1976).

formation (Dane, 1929). The unit is referred to as the Arkadelphia Formation in this paper because it is not all marl or clay.

The Arkadelphia Formation was described in detail by Dane (1929), who (p. 145) pointed out that the it is 36 to 45 m thick and "... chiefly a dark gray and black marl and marly clay, weathering light gray and containing some beds of hard calcareous gray sandstone, gray sandy clay, sandy limestone, dense, concretionary limestone, and white, impure chalk. The marl is prevailingly free from palpable sand. When perfectly fresh it appears laminated or bedded. It is usually more or less weathered and appears poorly bedded, or massive...." Dane (1929) considered the Arkadelphia to disconformably overlie the Nacatoch and to be disconformably overlain by the Paleocene Midway Group.

OSTRACODES OF THE ARKADELPHIA

Previous Work

Ostracodes from the Arkadelphia Formation were first described by Israelsky (1929), who reported eight species. Skinner (1956) found 28 species in the basal part of the Arkadelphia, and Crane (1965) identified 16 species from two Arkadelphia samples. The ostracodes of the Arkadelphia were studied by R. G. Drouant (1959) as part of an unpublished Ph.D. dissertation at Louisiana State University. References to studies of Upper Cretaceous ostracodes from other formations in the Coastal Province can be found in Brouwers and Hazel (1978) and Hazel and Brouwers (1982). The basic reference for Cretaceous ostracode work in the Atlantic and Gulf Coastal Province is the excellent 1929 monograph of C. I. Alexander on the ostracodes of Texas, as well as his subsequent papers (Alexander, 1933, 1934, 1936).

Collections

Because the Arkadelphia is predominantly a soft clay, good exposures are rare. Fresh exposures weather rapidly and may be covered entirely by vegetation in a matter of months. As a result, the availability of information on and sample materials from the Arkadelphia is rather poor. The Arkadelphia was sampled by one of us (JEH) in the late

1970's, but the samples were not productive. The first author sampled the Arkadelphia in 1990, and those samples were also barren. However, faunal slides based on Arkadelphia samples are present in the H. V. Howe Microfossil Collection at Louisiana State University. The Deaderick Collection (see Henbest, 1946) of the National Museum of Natural History, Washington, D. C., also contains valuable collections from the Arkadelphia Formation. The faunal slides used by Drouant (1959) were made available to us by Dr. Drouant and this material has been updated and re-identified. The Howe, Deaderick, and Drouant Collections form the basis of this paper. Locality data are given in Table 1.

The Assemblage

Thirty six species of podocopid ostracodes representing 24 genera occur in the Arkadelphia (Table 2). The platycopid genus Cytherella is also present and abundant. However, the unornamented valves and indistinctive shapes presented difficulties in determining how many species are present. The Cytherella are grouped together under Cytherella spp. The ornamented platycopid genus Cytherelloidea is conspicuous by its absence. Figures 4–8 give SEM micrographs of the species of the Arkadelphia, except for a rare species of Bythocypris and Cytherella spp.

Dominant Elements

The ostracode assemblage is dominated by specimens of Cytherella spp. (16.86 percent) Brachycythere rhomboidalis (Berry, 1925) (13.99 percent), Haplocytheridea renfroensis Crane, 1965 (12.90 percent), Haplocytheridea bruceclarki (Israelsky, 1929) (8.44 percent), and Brachycythere ovata (Berry, 1925) (5.22 percent) (Table 2). Other less abundant species are also characteristic of the Arkadelphia. These include Antibythocypris macropora (Alexander, 1929), Ascetoleberis hazardi (Israelsky, 1929), Aversovalva fossata (Skinner, 1956), Brachycythere ledaforma (Israelsky, 1929), Curfsina communis (Israelsky, 1929), Cytheromorpha arbenzi (Skinner, 1956), Escharacytheridea micropunctata (Alexander, 1929), and Veenia arachoides (Berry, 1925).

Paleoenvironment

The ostracodes of the Arkadelphia Formation indicate that the sediments were deposited in a normal marine environment with no influence of fresh water. Experience has shown that, in general, in the Upper Cretaceous the abundance of members of the Family Cytherideidae, such as Haplocytheridea, Antibythocypris, and Escharacytheridea, as opposed to members of the Family Trachyleberididae, such as Ascetoleberis and Veenia suggests an inner-sublittoral site of deposition. Table 3 shows the occurrence of the ostracodes in the samples studied.

Ostracode Biostratigraphy

The dominant and generally characteristic species of the Arkadelphia Formation also occur in older units of the Navarro Group (Hazel and Brouwers, 1982). However, some minor elements of the Arkadelphia assemblage are important biostratigraphically and their occurrence in the Arkadelphia, and elsewhere led us to the conclusion that the Platycosta lixula Zone of Hazel and Brouwers (1982) can be divided. A new interval zone is proposed and discussed below.

VEENIA PARALLELOPORA ZONE

Definition

The lower boundary is defined by the evolutionary first appearance of Veenia parallelopora (Alexander, 1929). The upper boundary is defined by the first evolutionary appearance of Brachycythere plena Alexander, 1934.

Characterization

Brachycythere foraminosa Alexander, 1934, is a valuable form for recognizing the chronozone in the absence of Veenia parallelopora. It has virtually the same range, but extends into the basal Tertiary where the oldest Tertiary is present (Alexander, 1929; Alexander in Scott, 1934). Cytheromorpha arbenzi first appears at the same level as

Table 1 Sample localities.

Sample	Locality	Collection
A-1	Highway 67, roadside ditch, eastside, 7.6 kilometers south-southwest of railroad station in Arkadelphia, Clark County , Arkansas.	Deaderick Collection #AM 358
A-2	Center NE 1/4, NW 1/4, Sec 12, T 8 S, R 20 W. In the southeast quadrant of the junction of Arkansas state road 26 and U.S. 67.	Drouant Collection S-1, S-2, S-3
A-3	Junction highways 67 and 26, south of Arkadelphia, Arkansas.	HVH Collection #KU 94-95
A-4	Highway 67, roadside ditch, eastside, 10.5 kilometers southwest of Missouri Pacific Railroad station in Arkadelphia, Clark County , Arkansas.	Deaderick Collection #AM 379
A-5	6.6 kilometers west of the Little Missouri River on the Prescott to Arkadelphia highway. NW 1/4, SW 1/4, T 10 S, R 22 W. On the south side of the highway in limited ditch exposures.	Drouant Collection R-1, R-2, R-3
A-6	Highway 29, between Hope and Blevins, 274 meters from Reid's (Harris') store, on side road to Washington, north side of road, Hempstead County, Arkansas.	Deaderick Collection #AM 218
A-7	5/12S/24W, near Emmett, Arkansas.	HVH Collection #KU 98
A-8	4.5 kilometers from junction state roads 32 and 29 going north toward Blevins from Hope, Hempstead County. 0.3 kilometers south of common corner Sec 33 and Sec 34, T 11 S, R 24 W, and Sec 3 and Sec 4, T 12 S, R 24 W. In hillsides and ditches east of road.	Drouant Collection Q-1, Q-2, Q-3, Q-4, Q-5, Q-6
A-9	Highway 4, 8 kilometers northwest of Hope, 91 meters east of airport beacon, Hempstead County, Arkansas.	Deaderick Collection #AM 217
A-10	5/13S/26W, Hempstead County, Arkansas.	HVH Collection #KU 97
A-11	4.2 kilometers north Missouri Pacific Railroad at McNab, Arkansas.	HVH Collection #HVH 451
A-12	From 1.6 to 2.4 kilometers south of McNab on the road to Fulton, Hempstead County; SE 1/4, SE 1/4, Sec. 6, T 13 S, R 26 W, and NE 1/4, NE 1/4, Sec 7, T 13 S, R 26 W. In the ditch west of the road.	Drouant Collection P-1, P-2, P-3, P-4, P-5, P-6, P-7

Table 2 Abundance of ostracode species of the Arkadelphia Formation. D = dominant species (>15%) S = secondary species (5–15%), M = minor species (< 5% but occur in more than one sample), R = rare species (< 5% and occur in only one sample)

Alatacythere aff. A. serrata (Bonnema, 1940)	M
Antibythocypris gooberi Jennings, 1936	M
Antibythocypris macropora (Alexander, 1929)	M
Argilloecia sp.	M
Ascetoleberis hazardi (Israelsky, 1929)	M
Aversovalva fossata (Skinner, 1956)	M
Bairdoppilata pondera Jennings, 1936	M
Brachycythere foraminosa Alexander, 1934	M
Brachycythere ledaforma Israelsky, 1929	M
Brachycythere ovata (Berry, 1925)	S
Brachycythere rhomboidalis (Berry, 1925)	S
Bythocypris sp.	M
Curfsina communis (Israelsky, 1929)	M
Cytherella spp.	D
Cytheromorpha arbenzi (Skinner, 1956)	M
Cytheromorpha sp.	M
Cytheropteron castorensis Butler and Jones, 1957	M
Cytheropteron navarroense Alexander, 1929	M
Cytherura cretacea Alexander, 1936	R
Escharacytheridea magnamandibulata Brouwers and Hazel, 1978	M
Escharacytheridea micropunctata (Alexander, 1929)	M
Eucythere sohli Brouwers and Hazel, 1980	M
Fissocarinocythere huntensis (Alexander, 1929)	M
Haplocytheridea bruceclarki (Israelsky, 1929)	S
Haplocytheridea aff. H. everetti (Berry, 1925)	M
Haplocytheridea renfroensis Crane, 1965	S
Krithe whitecliffensis Crane, 1965	S
Loxoconcha cretacea Alexander, 1936	M
Loxoconcha clinocosta Crane, 1965	M
Orthonotacythere hannai (Israelsky, 1929)	M
Paracypris sp.	M
Platycosta lixula (Crane, 1965)	M
Pterygocythere saratogana (Israelsky, 1929)	M
Veenia adkinsi Smith, 1978	R
Veenia arachoides (Berry, 1925)	M
Veenia parallelopora (Alexander, 1929)	M
Xestoleberis sp.	M

Table 3 Distribution of ostracode species in each sample from the Arkadelphia Formation. Each valve was counted as one specimen, and each carapace was counted as two. "Total" indicates number of specimens of a species in all samples.

Species	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	Total	% Total
Cytherella spp.	2	83	68	4	120	173	43	244	231	77	499	131	1675	16.86
Brachycythere rhomboidalis	0	52	62	0	63	264	43	182	310	61	244	109	1390	13.99
Haplocytheridea renfroensis	2	92	241	0	67	158	44	124	85	166	195	107	1281	12.90
Haplocytheridea bruceclarki	0	30	143	0	62	28	95	111	68	12	88	60	838	8.44
Brachycythere ovata	0	24	14	0	45	117	1	70	105	4	83	56	519	5.22
Krithe whitecliffensis	0	16	70	0	74	28	46	78	98	2	50	40	502	5.05
Curfsina communis	1	10	3	0	19	56	0	80	75	16	91	50	401	4.04
Platycosta lixula	0	20	43	0	24	10	0	69	115	4	77	33	395	3.98
Ascetoleberis hazardi	0	17	29	0	33	24	3	94	93	12	47	37	389	3.92
Brachycythere foraminosa	0	17	0	0	24	0	0	73	171	0	10	2	297	2.99
Escharacytheridea micropunctata	2	29	66	0	36	54	8	21	17	4	11	29	277	2.79
Antibythocypris macropora	0	32	91	1	15	3	20	17	24	4	11	27	245	2.47
Alatacythere aff. A. serrata	0	8	20	0	14	7	36	39	54	0	19	28	225	2.26
Antibythocypris gooberi	0	2	2	0	29	3	0	68	31	0	0	6	141	1.42
Brachycythere ledaforma	0	0	10	0	14	18	0	43	22	2	22	2	133	1.34
Bairdoppilata pondera	0	0	0	0	25	7	0	48	18	0	6	16	120	1.21
Loxoconcha clinocosta	0	14	16	0	19	0	2	18	30	0	2	8	109	1.10
Argilloecia sp.	0	12	16	0	2	0	2	39	18	2	2	10	103	1.04
Veenia parallelopora	0	0	0	0	2	9	0	17	62	0	0	0	90	0.91
Fissocarinocythere huntensis	0	0	0	0	6	11	0	28	34	0	2	8	89	0.90
Escharacytheridea magnamandibulata	0	0	2	0	10	15	0	18	14	2	5	14	80	0.80
Cytheropteron navarroense	0	9	3	0	8	8	2	26	15	0	5	2	79	0.80
Eucythere sohli	0	0	0	0	4	0	0	14	50	0	0	6	74	0.74
Cytheromorpha arbenzi	0	0	1	0	6	0	0	33	30	0	0	1	71	0.71
Haplocytheridea aff. H. everetti	0	35	20	5	0	0	0	0	0	0	0	0	60	0.60
Cytheromorpha sp.	0	0	6	0	2	0	0	21	24	0	0	4	57	0.57

table con'd.

Species	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12	Total	% Total
Bythocypris sp.	0	2	0	0	4	0	0	2	48	0	0	0	56	0.56
Pterygocythere saratogana	0	2	8	0	6	2	0	15	11	2	2	6	54	0.54
Orthonotacythere hannai	0	1	4	0	7	3	0	22	13	0	0	3	53	0.53
Xestoleberis sp.	0	0	0	0	0	1	0	14	20	0	0	2	37	0.37
Paracypris sp.	0	2	0	0	0	0	2	12	18	0	0	0	34	0.34
Loxoconcha cretacea	0	0	3	0	0	0	0	9	10	0	2	0	24	0.24
Cytheropteron castorensis	0	6	4	0	1	0	0	0	2	0	0	0	13	0.13
Aversovalva fossata	0	1	0	0	0	0	0	8	4	0	0	0	13	0.13
Veenia arachoides	0	0	0	0	0	2	0	0	4	0	0	0	6	0.06
Cytherura cretacea	0	0	0	0	0	0	0	0	2	0	0	0	2	0.02
Veenia adkinsi	0	0	0	0	0	2	0	0	0	0	0	0	2	0.02
Total specimens per sample	7	515	946	10	741	1003	347	1657	2067	370	1473	797	9934	= Total

number of specimens

Veenia parallelopora and thus represents an alternate event for recognition of the base of the chronozone of the V. parallelopora Zone in Arkansas. However, Cytheromorpha arbenzi is as yet only known from the Arkadelphia and may be only of local importance. The extinction of Fissocarinocythere pidgeoni (Berry, 1925) is at approximately the same point in time as the first evolutionary appearance of Veenia parallelopora (see Hazel and Brouwers, 1982). Other forms that may be used as chronostratigraphically characterizing species, but which need further study to confirm their utility, are Veenia adkinsi Smith, 1978, and Anticythereis copelandi Smith, 1978.

Remarks

Veenia parallelopora ranges from the base of the Arkadelphia (Cythere ponderosana Israelsky of Skinner, 1956) to the upper part of the Arkadelphia Formation (locality A–9). In northeast Texas V. parallelopora is known to occur in correlatives of the Arkadelphia Formation. Alexander (1929) reports its last occurrence to be just below the Cretaceous/Tertiary boundary. In the eastern Gulf part of the Atlantic and Gulf Coastal Province, we have seen V. parallelopora in the upper part of the Prairie Bluff Formation, which is in the upper part of the species chronozone. In contrast, Brachycythere foraminosa has only been observed in the upper part of the Arkadelphia in Arkansas and the upper Kemp Clay (as used by Stephenson, 1941) and basal Tertiary (see the statements by C. I. Alexander in Scott, 1934, p. 1153) in Texas. B. foraminosa has, however, been recorded from the basal to the uppermost Prairie Bluff in the eastern Coastal Province (Brachycythere sp. B of Smith, 1978). Neither Veenia parallelopora nor Brachycythere foraminosa occur consistently in all samples, but none of the taxa that do are restricted to the latest Cretaceous units (except possibly Cytheromorpha arbenzi). If the long Platycosta lixula Zone is to be divided, these species have to be used.

RELATIONSHIP OF THE ARKADELPHIA FORMATION AND THE VEENIA PARALLELOPORA ZONE TO OTHER ZONATIONS AND EVENTS

On the basis of molluscs, the Arkadelphia Formation can be placed in the upper part of the Exogyra costata Zone (Dane, 1929). The Haustator bilira Assemblage Zone was proposed by Sohl (1977) for coastal plain rocks of Late Maastrichtian age, including the Arkadelphia Formation.

Cushman (1949) reported 116 species of benthic and planktic foraminifers from 11 localities of the Arkadelphia Formation. These include the planktic species Racemiguembelina fructicosa (Egger, 1899) and Planoglobulina acervulinoides (Egger, 1899). Pessagno (1969) recorded a moderately diverse planktic foraminiferal assemblage from the upper part of the Arkadelphia formation just south of McNab in Hempstead County, Arkansas. Pessagno placed this sample in his middle Maastrichtian Globotruncana gansseri Assemblage Subzonule. Pessagno believed (see also Pessagno et al., 1990; Montgomery et al., 1992) that there are no late Maastrichtian deposits in northeastern Texas and Arkansas. This conclusion is based primarily on the absence of Abathomphalus mayaroensis (Bolli, 1951), which is used by many workers as an upper Maastrichtian zone fossil. However, other data do not support this conclusion. Abathomphalus mayaroensis was probably a deeper water dweller and is absent because of the sublittoral conditions under which the Arkadelphia and its regional correlatives were deposited. Douglas and Savin (1978), in a study of the depth stratification of planktic foraminifers, point out that the Cretaceous assemblages of Arkansas are dominated by shallow dwelling types. They consider double-keeled globotruncanids (such as Abathomphalus mayaroensis) to be deeper water forms, although they do not mention A. mayaroensis by name. Fifteen miles along strike northeast of Pessagno's locality at McNab, and also near the top of the Arkadelphia, Bramlette and Martini (1964) had already reported a late Maastrichtian calcareous nannoplankton assemblage with

Micula murus (Martini, 1961) and Ceratolithoides kamptneri Bramlette and Martini, 1964.

The evolutionary first appearance datum (FAD) of Ceratolithoides kamptneri is virtually the same as the the FAD of Abathomphalus mayaroensis, whereas the FAD of Micula murus is about 2.5 my later and only 2.0 my before the end of the Cretaceous (Figure 9). The chronozone of the Veenia parallelopora Zone correlates with that of Ceratolithoides kamptneri. The latter first occurs in the basal Prairie Bluff Formation in Alabama (Worsley, 1974) with Brachycythere foraminosa . Micula murus apparently only occurs in the upper part of the Veenia parallelopora Chronozone. Bramlette and Martini (1964) only reported on one Arkadelphia sample, but in Alabama Worsley (1974) and Thierstein (1981) indicated that Micula murus is only found in the upper part Prairie Bluff Formation. Jiang and Gartner (1986) reported Micula murus from the upper 18 m of the Kemp Clay at a locality in the Brazos River valley. Recently, Habib et al. (1992) recorded the very late Maastrichtian nannofossil, Micula prinsii , differentiated from M. murus by Perch-Nielsen (1979), from the uppermost 60 cm of the Prairie Bluff Formation in the Braggs, Alabama, area. Jiang and Gartner (1986) indicated the presence of M. prinsii morphotypes in the upper part of the Kemp Clay in northeastern Texas, but they did not differentiate M. prinsii from M. murus in their occurrence table.

Futher evidence of an abundance of late Maastrichtian deposits in the Gulf part of the Coastal Province comes from ammonite occurrences, which were apparently not considered by Pessagno (1969), Smith and Pessagno (1973), and Pessagno et al. (1990). For example, Discoscaphites roanensis was described from the Kemp Clay in Texas by Stephenson (1941, p. 429), where it is found "...within 15 or 20 feet of its top." This species occurs in the Western Interior where it is used as a zone fossil (Gill and Cobban, 1966; Obradovich and Cobban, 1975). Obradovich (1988, p. 765) shows a high temperature radiometric age of 69.0 ± 0.7 on a bentonite that occurs stratigraphically a short interval below the Discoaster roanensis Zone.

The nannoplankton and ammonite data indicate that not only is there late Maastrichtian deposits in the coastal plain, but that there is a considerable amount. The Abathomphalus mayaroensis Zone is missing because the zone-defining taxon is not present, but its chronozone is present as evidenced by other fossil events. The assertion by Pessagno (1969), Pessagno et al. (1990), Montgomery et al. (1992) and Smith and Pessagno (1973) that youngest Cretaceous deposits in the northeast Texas and southwestern Arkansas area are of middle Maastrichtian age is incorrect. Similarly, the recent dating of the Prairie Bluff Formation of Mississippi and Alabama as middle Maastrichtian (Mancini et al., 1989) is in error.

Figure 4 Scanning electron photomicrographs of the ostracode species: 1, Alatacythere aff. A. serrata (Bonnema, 1940), exterior view of female left valve, x 100; 2, Antibythocypris gooberi Jennings, 1936, exterior view of female left valve, x 100; 3, Antibythocypris macropora (Alexander, 1929), exterior view of female left valve, x 100; 4, Argilloecia sp. exterior view of left valve of carapace, x 150; 5, 6, Ascetoleberis hazardi (Israelsky, 1929), 5, exterior view of female left valve, x 100, 6, ventral view of carapace, x 100; 7, Bairdoppilata pondera Jennings, 1936, exterior view of left valve, x 50; 8, Brachycythere foraminosa Alexander, 1934, exterior view of female left valve, x 100.

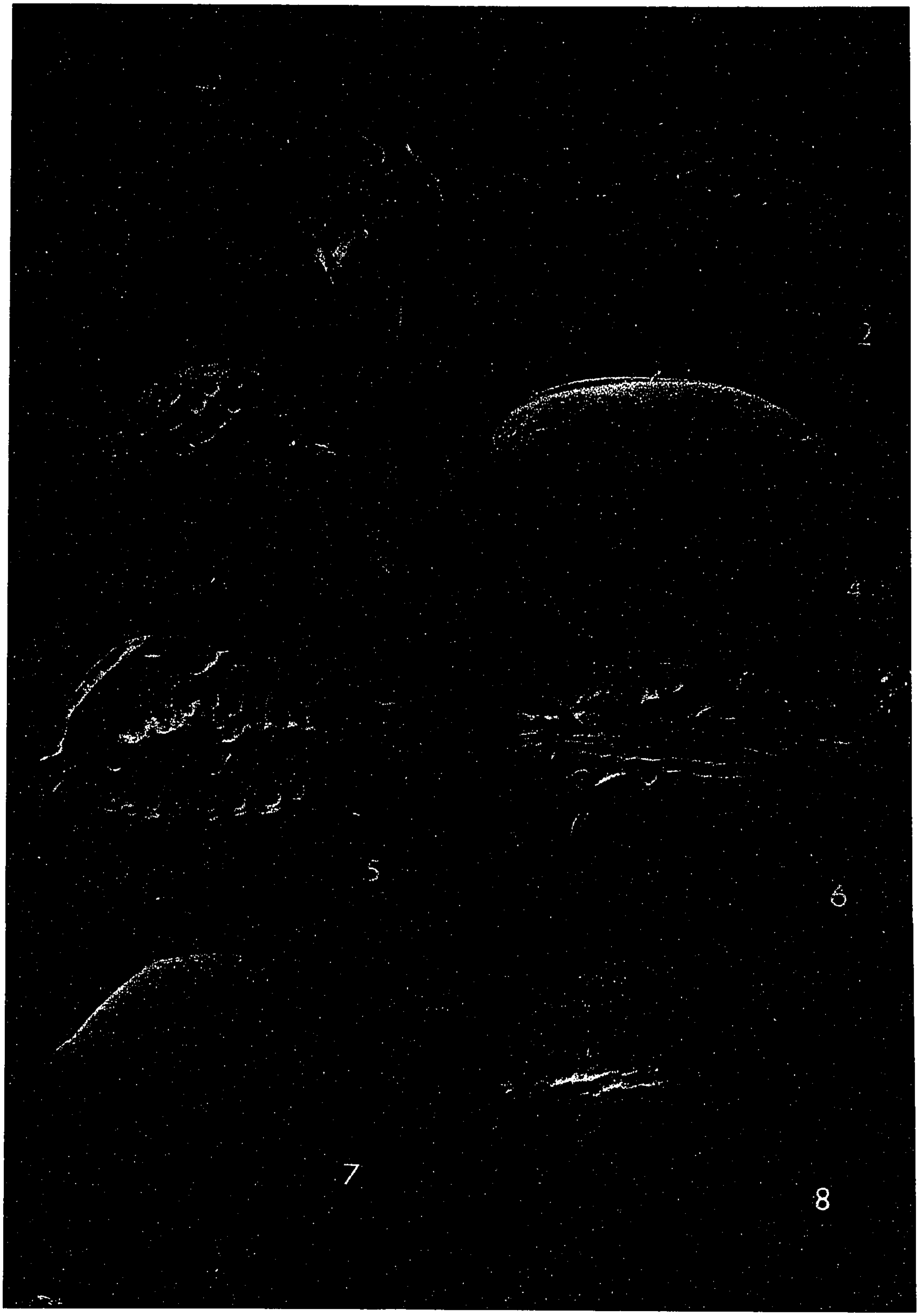

2
4
5
6
7
8

Figure 5 Scanning electron photomicrographs of the ostracode species: 1, Brachycythere ledaforma Israelsky, 1929, exterior view of female right valve, x 100; 2, Brachycythere ovata (Berry, 1925), exterior view of female left valve, x 50; 3, Brachycythere rhomboidalis (Berry, 1925), exterior view of female left valve, x 75; 4, Curfsina communis (Israelsky, 1929), exterior view of female left valve, x 100; 5, Platycosta lixula (Crane, 1965), exterior view of female left valve, x 100; 6, Cytheromorpha arbenzi (Skinner, 1956), exterior view of female left valve, x 200; 7, Cytheromorpha sp., exterior view of left valve, x 200; 8, Cytheropteron castorensis Butler and Jones, 1957, exterior view of female right valve, x 100.

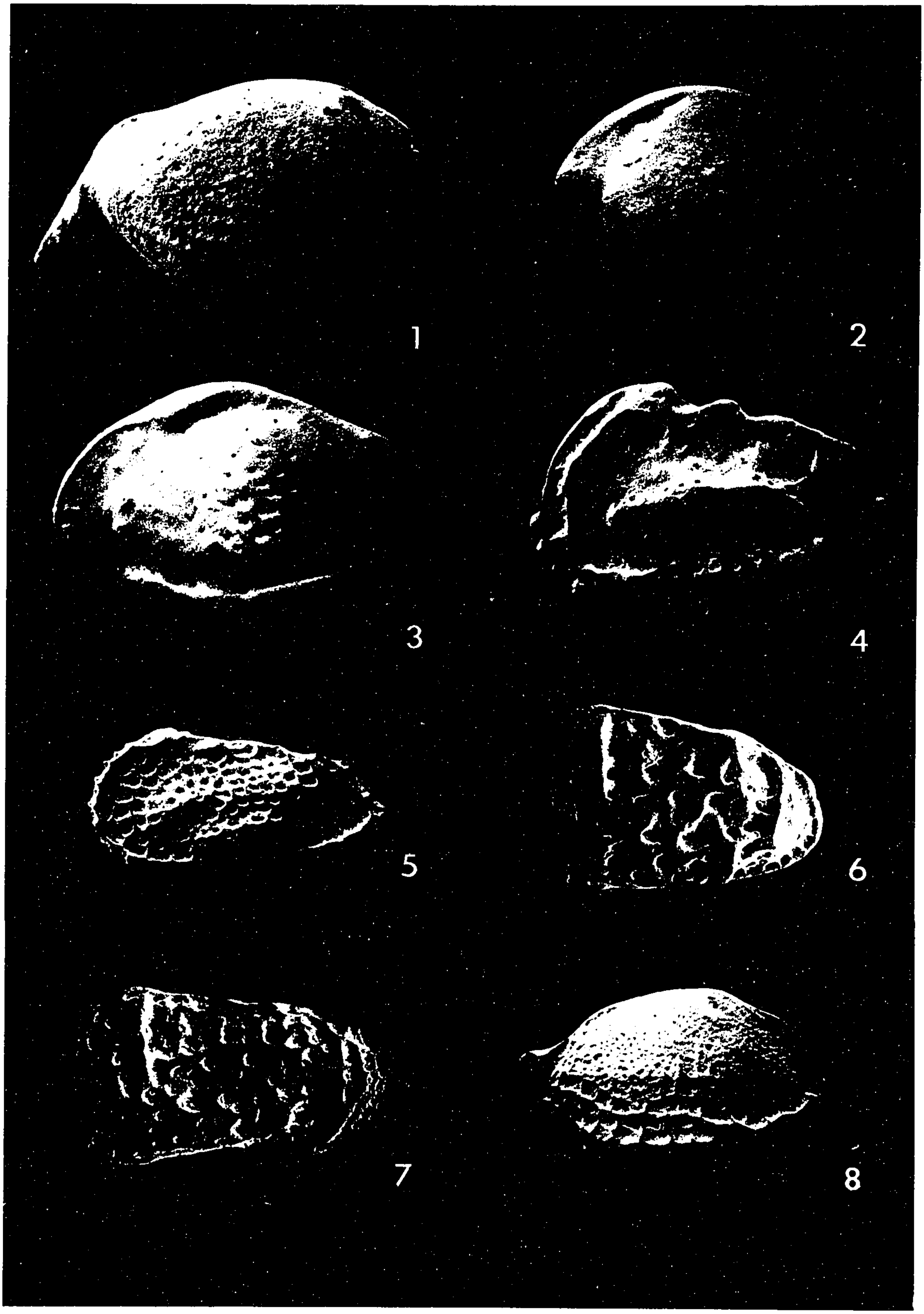

1
2
3
4
5
6
7
8

Figure 6 Scanning electron photomicrographs of the ostracode species: 1, 2 Cytheropteron navarroense Alexander, 1929, 1, exterior view of right valve, x 100, 2, ventral view of carapace, x100; 3, Aversovalva fossata (Skinner, 1956), exterior view of left valve, x 200; 4, Cytherura cretacea Alexander, 1936, exterior view of left valve, x 200; 5, Escharacytheridea magnamandibulata Brouwers and Hazel, 1978, exterior view of female left valve, x 100; 6, Escharacytheridea micropunctata (Alexander, 1929), exterior view of female left valve, x 100; 7, Eucythere sohli Brouwers and Hazel, 1980, exterior view of female left valve, x 100; 8, Fissocarinocythere huntensis (Alexander, 1929), exterior view of female left valve, x 100.

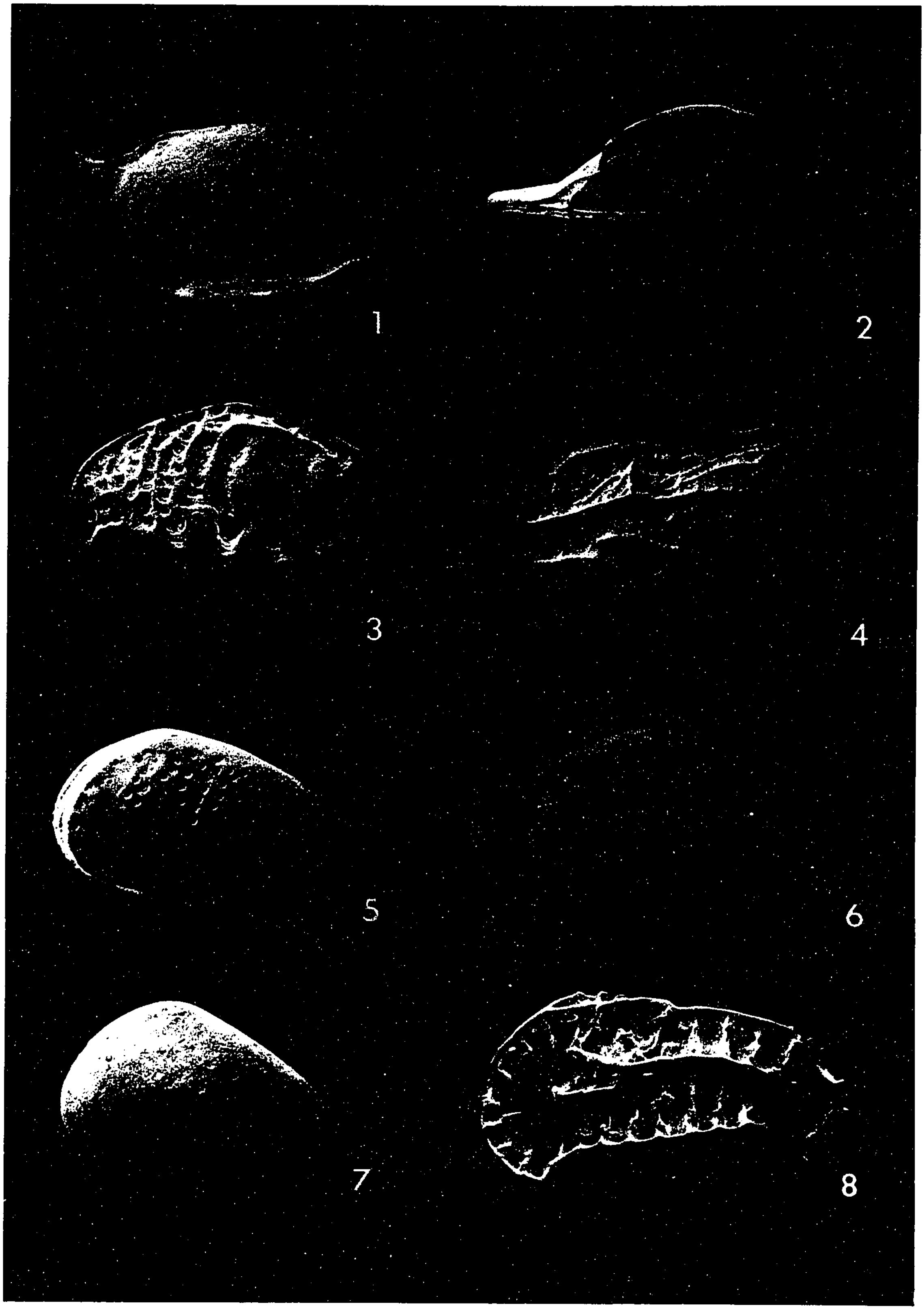

1
2
3
4
5
6
7
8

Figure 7 Scanning electron photomicrographs of the ostracode species: 1, Fissocarinocythere huntensis (Alexander, 1929), ventral view of carapace, x 100; 2, Haplocytheridea bruceclarki (Israelsky, 1929), exterior view of female left valve, x 150; 3, Haplocytheridea aff. H. everetti (Berry, 1925), exterior view of male left valve, x 100; 4, Haplocytheridea renfroensis Crane, 1965, exterior view of male left valve, x 100; 5, Krithe whitecliffensis Crane, 1965, exterior view of female left valve, x 100; 6, Loxoconcha clinocosta Crane, 1965, exterior view of male left valve, x 200; 7, Loxoconcha cretacea Alexander, 1936, exterior view of female left valve, x 200; 8, Orthonotacythere hannai (Israelsky, 1929), exterior view of right valve, x 100.

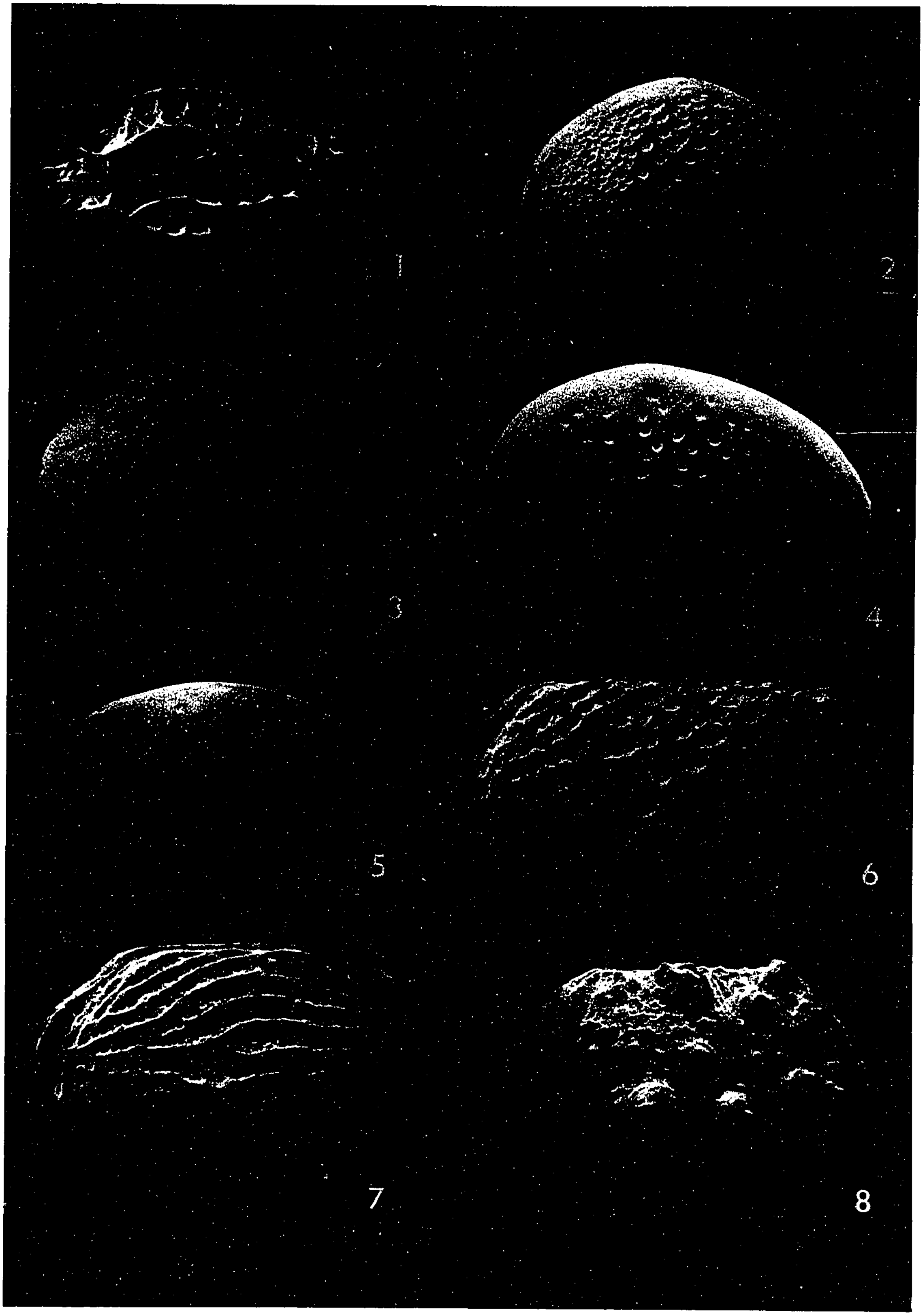

1
2
3
4
5
6
7
8

Figure 8 Scanning electron photomicrographs of the ostracode species: 1, Paracypris sp., exterior view of left valve, x 100; 2, Pterygocythere saratogana (Israelsky, 1929), exterior view of female left valve, x 75; 3, Veenia adkinsi Smith, 1978, exterior view of female right valve, x 100; 4, Veenia arachoides (Berry, 1925), exterior view of female left valve, x 100; 5, Veenia parallelopora (Alexander, 1929), exterior view of female left valve, x 100; 6, Xestoleberis sp., exterior view of left valve, x 100.

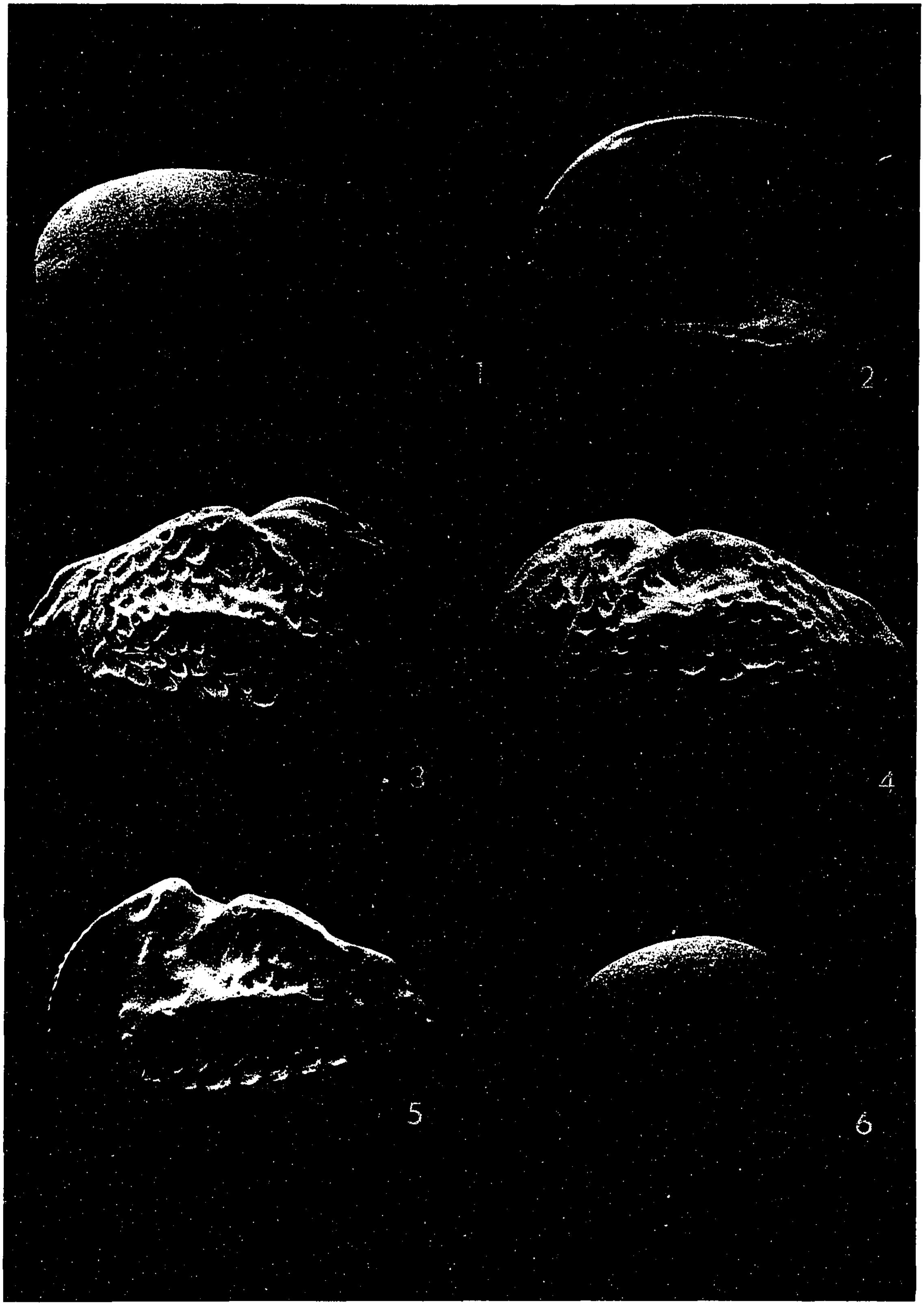
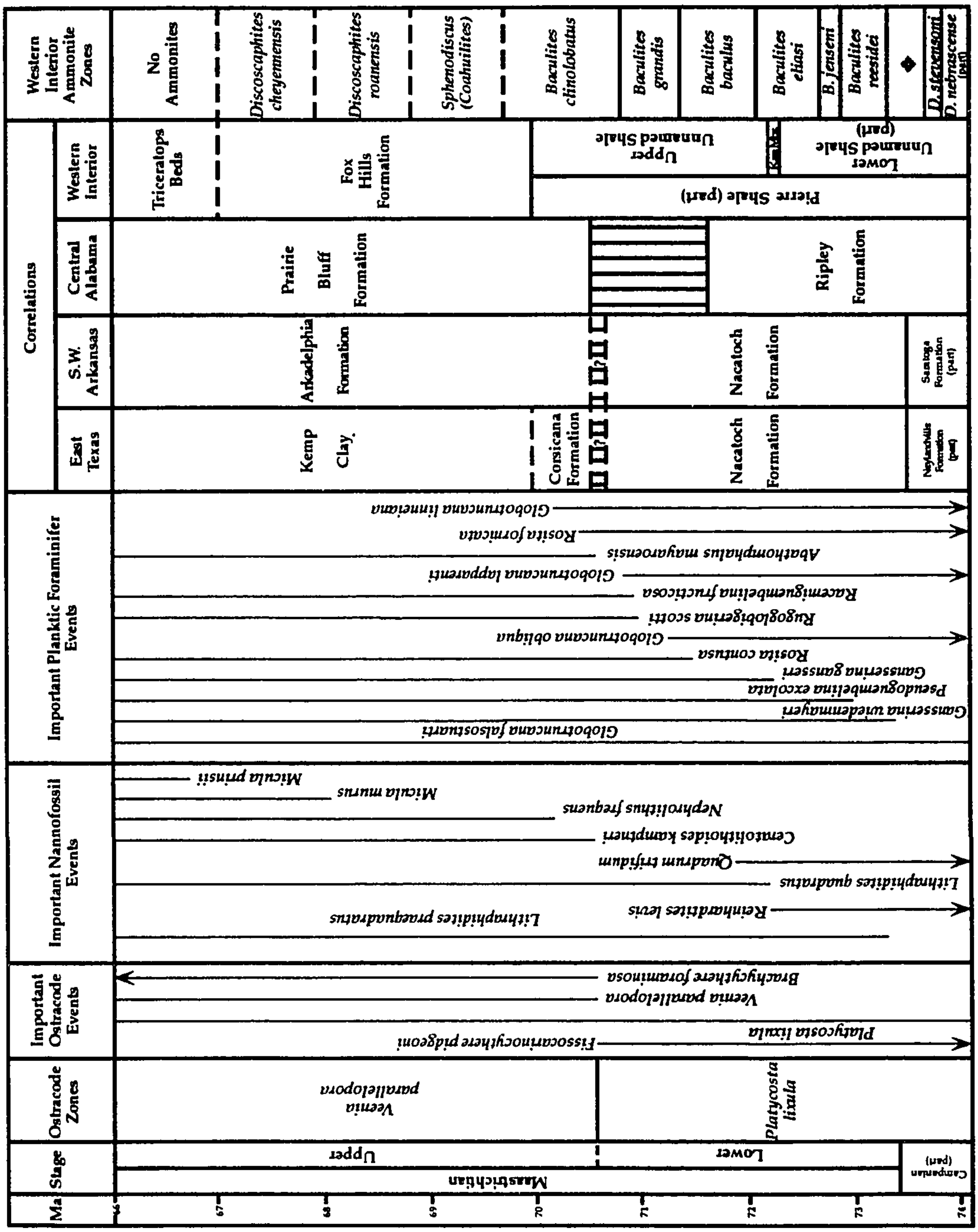

1
2
3
4
5
6

Figure 9 A summary chart covering the chronostratigraphic interval of the Platycosta lixula and Veenia parallelopara Zones. Ostracode evolutionary and extinction events are compared to Maastrichtian calcareous nannofossil and planktic foraminifer events. The relative positions of the microfossil events on the chart are based on their position in a graphic correlation-based composite standard (model) for the Upper Cretaceous. The conversion of the model values to time (Ma) is based on Hazel (1989, Figure 2). The correlation of the Arkadelphia Formation and other Maastrichtian lithostratigraphic units is also indicated in Figure 9. The duration of the hiatus at the unconformity at the top of the Nacatoch Formation in Northeast Texas and Arkansas is not known, but it is considered of small duration (Stephenson, 1941). The duration of the hiatus between the Ripley Formation and the Prairie Bluff Formation is better controlled. The base of the Prairie Bluff is no older than the evolutionary appearance of Ceratolithoides kamptneri, which ranges throughout the Prairie Bluff and is not found in the Ripley. The chronostratigraphic position of the top the Ripley in central Alabama was established by graphic correlation (unpublished data). In the two right hand columns of Figure 9, the microfossil events are compared to a standard section for the north central Western Interior, based primarily on the Red Bird, Wyoming, section (Gill and Gobban, 1966), and the sequence of ammonite zones (Gill and Cobban, 1966; Obradovich and Cobban, 1975). Below the base of the Fox Hills Formation the boundaries between lithostratigraphic and ammonite zonal units were established by graphic correlation. Above this level the Western Interior boundaries are estimates. The triangular symbol in the ammonite column between the Didymoceras stevensoni and Baculites reesidei Zones represents the Extiloceras jenneyi, Didymoceras cheyennense, Baculites compressus, and B. cuneatus Zones, which are of such short duration that they cannot be plotted at this scale.


Western Interior Ammonite Zones
No Ammonites
Discoscaphites cheyennensis
Discoscaphites roanensis
Sphenodiscus (Coahuilites)
Baculites clinolobatus
Baculites grandis
Baculites baculus
Baculites eliasi
B. jenseni
Baculites reesidei
D. stevensoni
D. nebrascense (part)
Correlations
Western Interior
Triceratops Beds
Fox Hills Formation
Upper Unnamed Shale
Lower Unnamed Shale (part)
Pierre Shale (part)
Central Alabama
Prairie Bluff Formation
Ripley Formation
S.W. Arkansas
Arkadelphia Formation
Nacatoch Formation
Saratoga Formation (part)
East Texas
Kemp Clay
Corsicana Formation
Nacatoch Formation
Neylandville Formation (part)
Important Planktic Foraminifer Events
Globotruncana linneiana
Rosita fornicata
Abathomphalus mayaroensis
Globotruncana lapparenti
Racemiguembelina fructicosa
Rugoglobigerina scotti
Globotruncana obliqua
Rosita contusa
Gansserina gansseri
Pseudoguembelina excolata
Gansserina wiedenmayeri
Globotruncana falsostuarti
Important Nannofossil Events
Micula prinsii
Micula murus
Nephrolithus frequens
Ceratolithoides kamptneri
Quadrum trifidum
Lithraphidites quadratus
Reinhardtites levis
Lithraphidites praequadratus
Important Ostracode Events
Brachycythere foraminosa
Veenia parallelopora
Platycosta lixula
Fissocarinocythere pidgeoni
Ostracode Zones
Veenia parallelopora
Platycosta lixula
Stage
Upper
Lower
Maastrichtian
Campanian (part)
Ma
67
68
69
70
71
72
73
74

REFERENCES TO CHAPTER II

Alexander, C. I., 1929, Ostracoda of the Cretaceous of North Texas. University of Texas Bulletin, 2907:1–137.

Alexander, C. I., 1933, Shell structure of the genus Cytheropteron, and species from the Cretaceous of Texas. Journal of Paleontology, 7:181–214.

Alexander, C. I., 1934, Ostracoda of the genera Monoceratina and Orthonotacythere from the Cretaceous of Texas. Journal of Paleontology, 8:57–67.

Alexander, C. I., 1936, Ostracoda of the genera Eucythere, Cytherura, and Loxoconcha from the Cretaceous of Texas. Journal of Paleontology, 10:689–694.

Berry, E. W., 1925, Upper Cretaceous ostracoda from Maryland. The American Journal of Science, 9:481–487.

Bolli, H., 1951, The genus Globotruncana in Trinidad, B. W. I. Journal of Paleontology, 25:187–199.

Bonnema, J. H., 1940, Ostracoden aus der Kreide des Untergrundes der nordostlichen Niederlande. Natuurhistorisches Maandblad, 27:130.

Bramlette, M. N. and Martini, E., 1964, The great change in calcareous nannoplankton fossils between the Maastrichtian and Danian. Micropaleontology, 10:291–322.

Brouwers, E. M. and Hazel, J. E., 1978, Ostracoda and correlation of the Severn Formation (Navarroan; Maestrichtian) of Maryland. Society of Economic Paleontologists and Mineralogists Paleontological Monograph 1, 52 p.

Brouwers, E. M. and Hazel, J. E., 1980, Eucythere sohli, a new name for Eucythere alexanderi Brouwers and Hazel, 1978. Journal of Paleontology, 54:1352.

Butler, E. A. and Jones, D. E., 1957, Cretaceous ostracoda of Prothro and Rayburns salt domes, Bienville Parish, Louisiana. Louisiana Geological Survey Geological Bulletin, 32:62 p.

Crane, M. J., 1965, Upper Cretaceous ostracodes of the Gulf Coast area. Micropaleontology, 11:191–254.

Cushman, J. A., 1949, The foraminiferal fauna of the Upper Cretaceous Arkadelphia Marl of Arkansas. U.S. Geological Survey Professional Paper 221–A, 19 p.

Dane, C. H., 1929, Upper Cretaceous formations of southwestern Arkansas. Arkansas Geological Survey Bulletin, 1:215 p.

Douglas, R. G. and Savin, S. M., 1978, Oxygen isotopic evidence for the depth stratification of Tertiary and Cretaceous planktic foraminifera. Marine Micropaleontology, 3:175–196.

Drouant, R. G., 1959, Stratigraphy and ostracoda of the Exogyra costata Zone of southwestern Arkansas. Unpubl. Ph.D. dissertation, Louisiana State University, Baton Rouge, 158 p.

Egger, J. G., 1899, Foraminiferen und ostrakoden aus den Kreidemergeln der oberbayerischen Alpen. Abhandlungen Bayerische Akademie der Wissenschaften, Muchen, Mathematisch–Naturwissenschaftliche Klasse, 21:1–230.

Gill, J. R. and Cobban, W. A., 1966, The Red Bird section of the Upper Cretaceous Pierre Shale in Wyoming, with a section on a new echinoid from the Cretaceous Pierre Shale of eastern Wyoming by P. M. Kier. U.S. Geological Survey Professional Paper 393–A, 73 p.

Habib, D., Moshkovitz S. and Kramer, C., 1992, Dinoflagellate and calcareous nannofossil response to sea-level change in Cretaceous-Tertiary boundary sections. Geology, 20:165–168.

Haley, B. R., Glick, E. E., Bush, W. V., Clardy, B. F., Stone, C. G., Woodward, M. B. and Zachry, D. L., 1976, Geologic map of Arkansas. United States Geological Survey.

Harris, G. D., 1894, The Tertiary geology of southern Arkansas. Arkansas Geological Survey Annual Report for 1892, 2:15.

Hazel, J. E., 1989, Chronostratigraphy of Upper Eocene microspherules. Palaios, 4:318-329.

Hazel, J. E. and Brouwers, E. M., 1982, Biostratigraphic and chronostratigraphic distribution of ostracodes in the Coniacian–Maastrichtian (Austinian–Navarroan) in the Atlantic and Gulf Coastal Province, p. 166–198. In R. F. Maddocks (ed.), Texas Ostracoda. Department of Geosciences, University of Houston, Houston.

Henbest, L. G., 1946, Deaderick Collection of Foraminifera. Journal of Paleontology, 20:517–518.

Hill, R. T., 1888, The Neozoic geology of southwestern Arkansas. Arkansas Geological Survey Annual Report for 1888, 2:53.

Holden, J. C., 1964, Upper Cretaceous ostracods from California. Palaeontology, 7:393–429.

Israelsky, M. C., 1929, Upper Cretaceous Ostracoda of Arkansas. Arkansas Geological Survey Bulletin, 2:3–29.

Jennings, P. H., 1936, A microfauna from the Monmouth and basal Rancocas Groups of New Jersey. Bulletins of American Paleontology, 23:161–235.

Jiang, M. J. and Gartner, S., 1986, Calcareous nannofossil succession across the Cretaceous/Tertiary boundary in east-central Texas. Micropaleontology, 32: 232–255.

Mancini, E. A., Tew, B. H. and Smith, C. C., 1989, Cretaceous-Tertiary contact, Mississippi and Alabama. Journal of Foraminiferal Research, 19:93104.

Martini, E., 1961, Nannoplankton aus dem Tertiar und der obersten Kreide von sw-Frankreich. Senckenbergiana Lethaea, 42:1–32.

Montgomery, H., Pessagno, E., Soegaard, K., Smith, C., Munoz, I. and Pessagno, J., 1992, Misconceptions concerning the Cretaceous/Tertiary boundary at the Brazos River, Falls County, Texas. Earth and Planetary Science Letters, 109:593-600.

Obradovich, J. D., 1988, A different perspective on glauconitic as a chronometer for geologic time scale studies. Paleoceanography, 3:757-770.

Obradovich, J. D. and Cobban, W. A., 1975, A time scale for the Late Cretaceous of the Western Interior of North America, p. 31–54. In W. G. E. Caldwell (ed.), The Cretaceous System of the Western Interior of North America. Geological Association of Canada Special Paper 13.

Perch-Nielsen, K., 1979, Calcareous nannofossils from the Cretaceous between the North Sea and the Mediterranean. International Union of Geological Sciences Series A, 6:223–272.

Pessagno, E. A., Jr., 1969, Upper Cretaceous stratigraphy of the western Gulf Coast area of Mexico, Texas, and Arkansas. Geological Society of America Memoir 111, 139 p.

Pessagno, E. A., Jr., Longoria, J. F., Montgomery, H. and Smith, C. C., 1990, Misconceptions concerning the Cretaceous-Tertiary Boundary, Brazos River, Falls County, Texas. Geological Society of America Abstracts with Programs, 1990 Annual Meeting:A277.

Scott, G., 1934, Age of the Midway Group. Geological Society of America Bulletin, 45:1111-1158.

Skinner, H. C., 1956, Ostracoda from basal Arkadelphia Marl exposures near Hope, Arkansas. Gulf Coast Association of Geological Societies Transactions, 6:179–204.

Smith, C. C. and Pessagno, E. A., Jr., 1973, Planktonic foraminifera and stratigraphy of the Corsicana Formation (Maastrichtian) north-central Texas. Cushman Foundation for Foraminiferal Research, Special Publication 12, 68 p.

Smith, J. K., 1978, Ostracoda of the Prairie Bluff Chalk, Upper Cretaceous, (Maestrichtian) and the Pine Barren Member of the Clayton Formation, Lower Paleocene, (Danian) from exposures along Alabama state highway 263 in Lowndes County, Alabama. Gulf Coast Association of Geological Societies Transactions, 28:539–579.

Sohl, N. F., 1977, Utility of gastropods in biostratigraphy, p. 519–539. In E. G. Kauffman and J. E. Hazel (eds.), Concepts and methods of biostratigraphy. Downden, Hutchinson and Ross, Inc., Stroudsburg, Pennsylvania.

Stephenson, L. W., 1941, The larger invertebrate fossils of the Navarro Group of Texas. The University of Texas Publication, 4101:27–30.

Thierstein, H. R., 1981, Late Cretaceous nannoplankton and the change at Cretaceous-Tertiary boundary. Society of Economic Paleontologists and Mineralogists Special Publication 32:355–394.

Veatch, A. C., 1926, Geology and underground water resources of northern Louisiana and southern Arkansas. U.S. Geological Survey Professional Paper 46:28.

Worsley, T., 1974, The Cretaceous-Tertiary boundary event in the ocean, p. 94–125. In W. W. Hay (ed.), Studies in paleoceanography. Society of Economic Paleontologists and Mineralogists Special Publication 20.

CHAPTER III

PSEUDOMORPHS OF IMPACT SPHERULES FROM A CRETACEOUS-TERTIARY BOUNDARY SECTION AT SHELL CREEK, ALABAMA

(Published as article: Pitakpaivan, K., Byerly, G. R. and Hazel, J. E., 1994, Pseudomorphs of impact spherules from a Cretaceous-Tertiary boundary section at Shell Creek, Alabama: Earth and Planetary Science Letters, 124 (1-4), 49-56. Reproduced here with permission from the editor.)

INTRODUCTION

Spherules with distinctive morphologies, some with tektite glass remaining, have recently been found at the Cretaceous-Tertiary (K-T) boundary at Beloc, Haiti (Izett 1991; Izett and others, 1990; Maurrasse and Sen 1991), Arroyo El Mimbral, northeastern Mexico (Smit and others, 1992), DSDP Leg 77 Sites 536 and 540 (Alvarez and others, 1992), DSDP Sites 603 and 390 (Klaver and others, 1993), Shell Creek, Alabama and Lynn Creek, Mississippi (Pitakpaivan and Hazel 1992), Brazos River, Texas and Moscow Landing, Alabama (Jan Smit, 1993, written communication) (Figure 10). Glass preserved within the spherules in some sections, such as at Beloc and Mimbral, suggest that these spherules were originally tektites. These have been interpreted as supporting the hypothesis that the Chicxulub structure, on what is now the north coast of Yucatán (Penfield and Camargo, 1981), was the site of a K-T boundary impact as proposed by Hildebrand and others (1991) and Pope and others (1991). However, Stinnesbeck and others (1993) have reexamined K-T boundary sections in northeastern Mexico and have concluded that no evidence exists there for a large impact. They suggest that the abundant 1-5 mm spherules are diagenetic in origin. These spherules have calcite cores and clay rims, and no preserved glass or spinels.

At a few localities along the K-T contact in Alabama there is a sand layer at the base of the Tertiary between the Danian Pine Barren Member of the Clayton Formation and the underlying late Maastrichtian Prairie Bluff Formation. This has been refered to as the basal Clayton sand. A study by Mancini and others (1989) concluded that the K-T contact at the top of the Prairie Bluff Chalk is disconformable, and these sections do not represent complete stratigraphic records. During a biostratigraphic study of these localities, peculiar grains were observed in the basal Clayton sand at Shell Creek, Alabama (Pitakpaivan and Hazel, 1992). The basal Clayton sand contains objects with similar morphologies and size distribution to the Beloc and Mimbral spherules. The purpose of this paper is to provide further documentation (see Pitakpaivan and Hazel, 1992) of the Alabama occurrence of the spherules.

STRATIGRAPHIC FRAMEWORK

The Prairie Bluff Chalk is predominantly an impure sandy chalk and is the youngest Maastrichtian unit in central and western Alabama. It disconformably underlies the lower Paleocene Clayton Formation (Figure 11). The Prairie Bluff Chalk is within the Haustator bilira Assemblage Zone (Sohl and Koch, 1986). Smith and Mancini (1983) and Mancini and others (1989) have assigned the Prairie Bluff Chalk to middle Maastrichtian planktonic foraminiferal Globotruncana gansseri Subzone. However, recently, Habib and others (1992) and Olsson and Lui (1992) have pointed out that in places the uppermost Prairie Bluff contains the latest Maastrichtian nannofossil Micula prinsii Perch-Nielsen (see also Pitakpaivan and Hazel, 1994).

A nannofossil investigation of the Prairie Bluff Chalk at Shell Creek section has been performed by Dr. James Pospichal at Florida State University. The nannofossil assemblages are typical of the upper Maastrichtian. The important zone marker species recovered from the Prairie Bluff Chalk included Micula murus and Nephrolithus frequens, which indicate that it is assignable to nannofossil zone NC23 (Roth 1978). However, the marker for the topmost Maastrichtian, Micula prinsii, was not found. It is likely that a disconformity of a minor magnitude is present at Shell Creek.

The ostracode assemblages are also typical of the upper Maastrichtian. The Prairie Bluff Chalk contains Veenia parallelopora and Brachycythere foraminosa, which are indicative of the Veenia parallelopora Zone (Pitakpaivan and Hazel, 1994). Therefore, nannofossil and ostracode biostratigraphy confirms that upper Maastrichtian rocks are present. This clarifies the misconception that the Prairie Bluff Chalk is of middle Maastrichtian age and the disconformity at Shell Creek is of a greater magnitude.

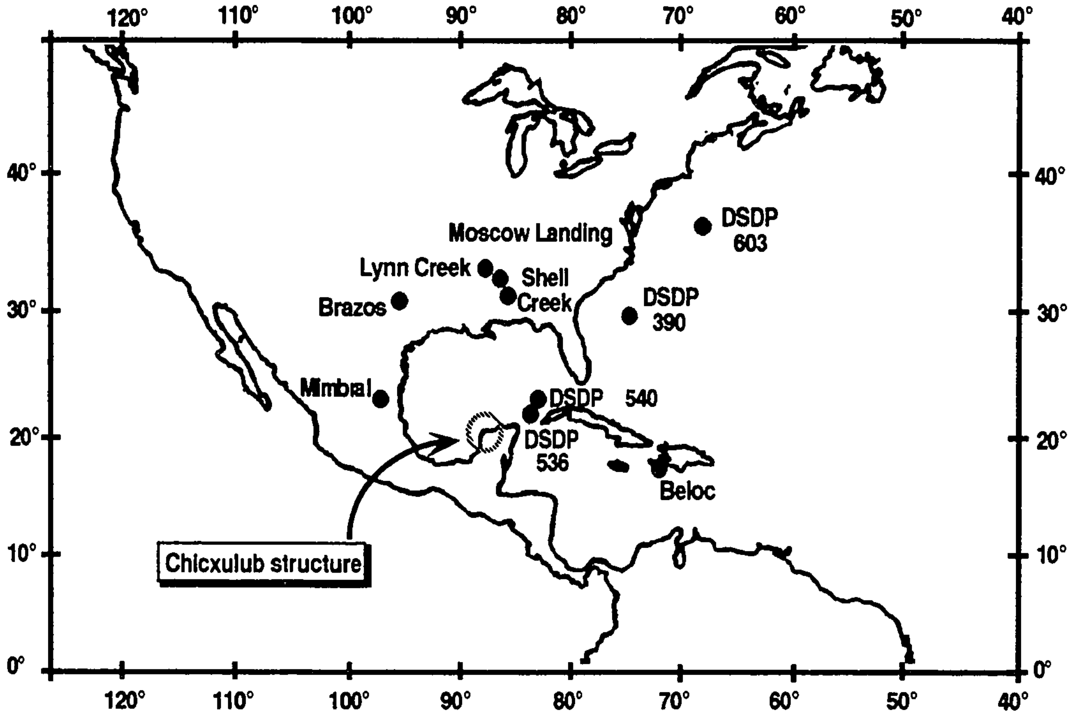


Figure 10 The location of the Shell Creek section, other Cretaceous-Tertiary boundary sections where spherules have been reported, and the proposed impact site, the Chicxulub feature. See text for references.

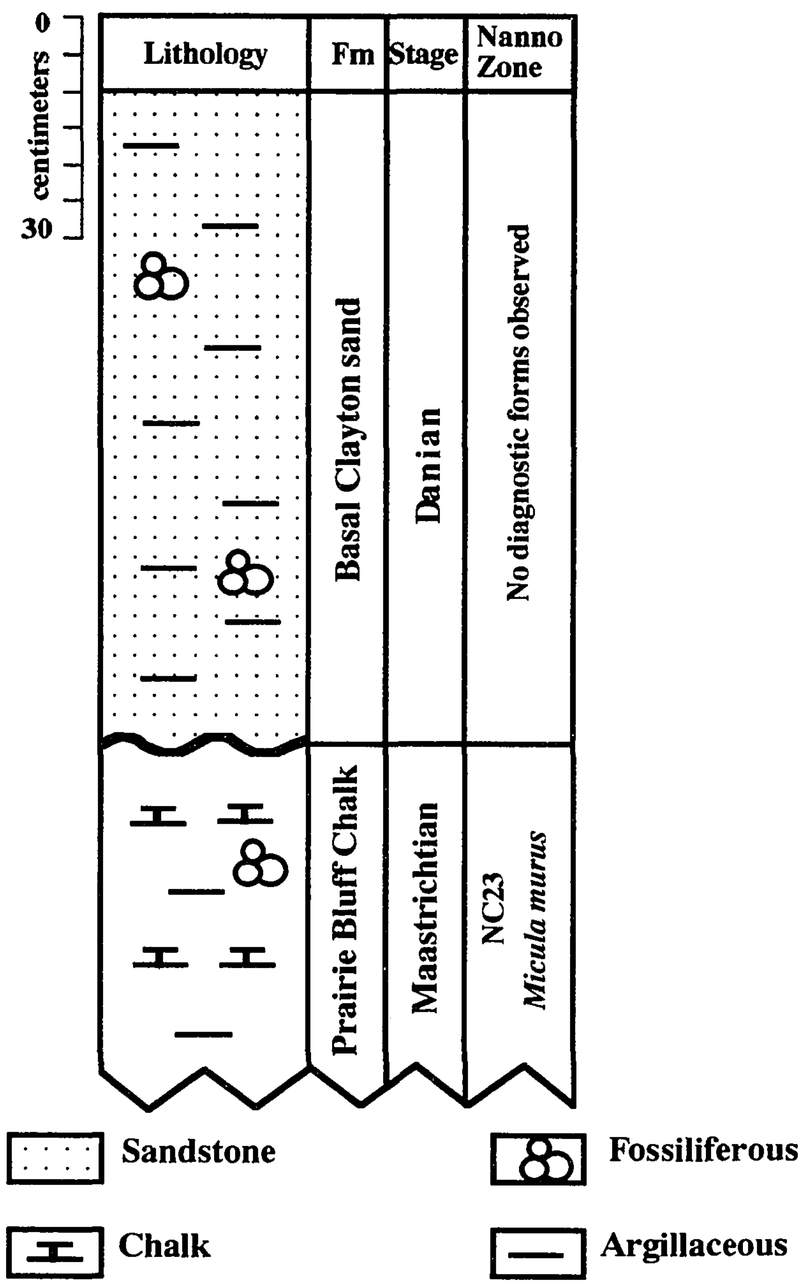


Figure 11 Upper Cretaceous and lower Paleocene section at Shell Creek. The Prairie Bluff Chalk is a bluish-gray, argillaceous, massive carbonate with a total thickness of 2.4 meters. An erosional surface separates the Prairie Bluff Chalk from the overlying basal Clayton sand of the Clayton Formation, which has a total thickness of 1.2 meters. The Maastrichtian nannofossil zone is that of Roth (1978). The Danian age of the Clayton sand at this locality is inferred from planktonic foraminifers reported from the upper part of the sand unit by (Mancini and other, 1989).

The basal Clayton sands are lenticular, discontinuous, irregularly-bedded sands that are generally overlain by a Clayton sandy marl or limestone bed. These basal sands contain an early Danian planktonic foraminiferal assemblage (Mancini and others, 1989). The basal Paleocene beds in Alabama and Mississippi are also commonly recognized as containing an abundance of reworked Cretaceous fossils that are intermixed with those of the basal Tertiary (LaMoreaux and Toulmin, 1959; Russell and others, 1983). Historically, these sands have not been well studied. They are present at some K-T sections in Alabama, such as Shell Creek, Moscow Landing, Prairie Bluff Landing and Mussel Creek. However, they are absent at some other Cretaceous-Tertiary sections in Alabama, such as the well-known roadcut section southeast of Braggs in Lowndes County that represents a nearly complete Cretaceous-Tertiary sequence (Habib and others, 1992).

The sands have been interpreted to be those that filled depressions on the eroded surface of the underlying Prairie Bluff Chalk, and probably represent lowstand fill of either incised valleys or scour channels and depressions (Mancini and others, 1989). At Shell Creek, the basal Clayton sand is massive, slightly argillaceous and calcareous. It contains glauconites, shark teeth, macrofossil and subangular lithic fragments. The Paleocene macrofossil, Ostrea pulaskensis, and reworked Cretaceous fossils, in the bottom part, have been observed in the Clayton sand. Mancini and others (1989) report Danian planktonic foraminifers from the Clayton sand, and assign it to early Danian planktonic foraminiferal Subbotina pseudobulloides Interval Zone.

OCCURRENCE AND MORPHOLOGY OF THE PSEUDOMORPHS

With the exception of in the upper 30 cm, dark green spherules were found in the Clayton basal sand bed at Shell Creek. These occur in abundance in the middle of the sand unit (Figure 3.11). The total thickness of the spherule bed is estimated to be at least 25 cm. A more precise determination of thickness is precluded by weathering. The Shell Creek sandstone is medium to coarse grained with abundant lithic clasts principally representing reworked Cretaceous carbonates. Carbonate clasts up to 1 cm in diameter can be seen in hand samples. Quartz and shell fragments are the dominant grain types, and glauconite pellets are common.

Examination of the spherules under a stereomicroscope reveals smooth, glossy, dark green clay jackets that rapidly swell and then disintegrate when they come in contact with water. Surrounded by this thin smectite jacket is a colorless calcite core that is generally massive. Some are composite. The surface of the calcite core is commonly sculptured with shallow pits, and occasionally with fine grooves and cracks (Figure 12).

A significant feature of the spherules is their morphology. They exhibit morphologies of splash-form tektites, including spheres, dumbbells, teardrops, prolate and oblate forms (Figure 12). Spherules that are irregular in morphology are not uncommon. We interpret these objects to be pseudomorphs of microtektites.

A 150 gm subsample was reduced to medium sand size and whole microtektite pseudomorphs were hand-picked under the stereoscope at 20x magnification. Figure 13 summarizes the size and morphology variation found in the 237 spherules obtained. During handpicking it was estimated that a comparable number of pseudomorphs were not picked because they were too damaged to yield size or morphology information. Simple spheres dominate the morphologies present, and their size distribution (1.24 ± 0.29 mm) is very similar to that reported by Izett (Izett, 1991) for spheres from Haiti (1.25 ± 0.49 mm) and Wyoming (0.92 ± 0.17 mm). Non-spherical microtektite pseudomorphs are generally larger with teardrops and prolate spheroids averaging 2.21 and 2.34 mm, respectively. Minor morphological types include oblate spheroids, dumbbells, and complex agglutinates. Two thin sections were counted to estimate the volume percentage of microtektite pseudomorphs in the layer of highest concentration. This layer contains 19% microtektite pseudomorphs. Visual estimates of microtektite pseudomorph volumes throughout the remainder of the

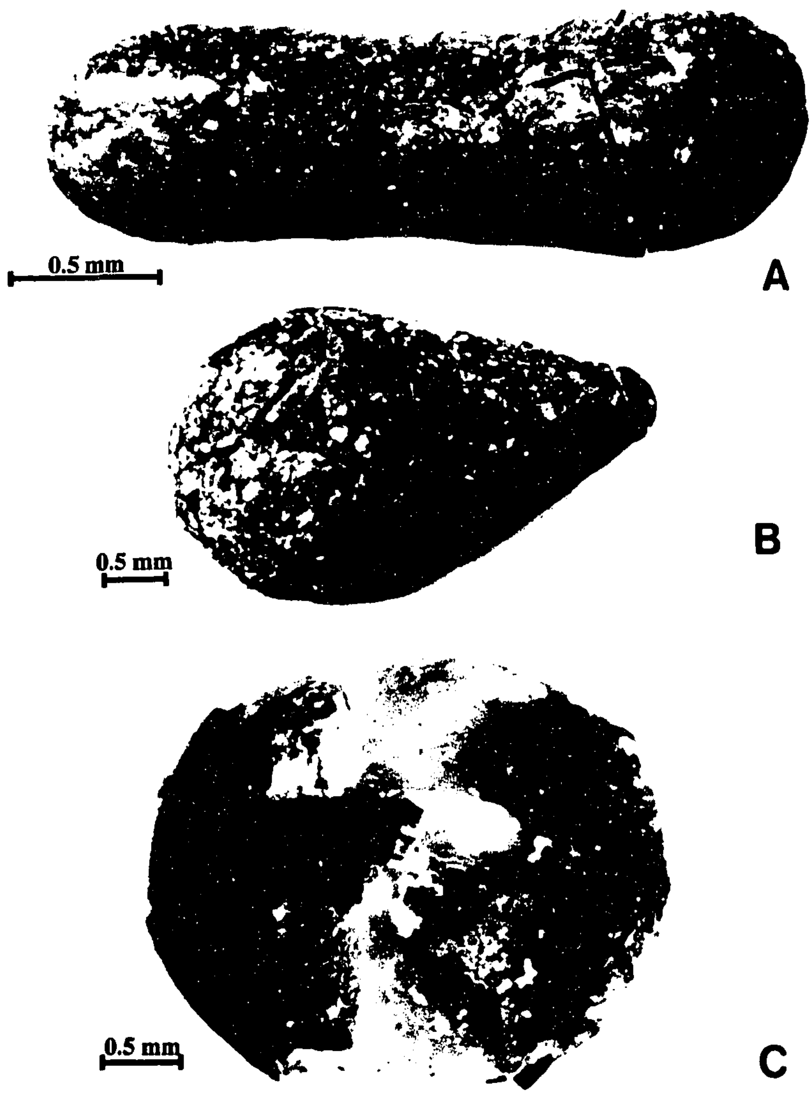


Figure 12 Photomicrographs of the pseudomorphs. A: dumbbell-shaped pseudomorph, 3.8 mm long. Smectite exterior layer is about 0.1 mm thick and displays dessication cracks that formed after the bulk sample was washed and hand picked. B: teardrop-shaped pseudomorph, 3.7 mm long. C: disc-shaped, 2.7 mm diameter, showing smectite shell enclosing an altered core. A portion of the exterior smectite layer has been removed to reveal the calcite core. Note sculptured surface of calcite core consisting of pits.

sandstone bed suggest much smaller percentages, perhaps 1-2%. These estimates would yield a total impact spherule fluence of about 2 gm/cm^2, somewhat less than at Haiti (Izett, 1991), but several orders of magnitude greater than at Petriccio, Italy (Montanari, 1991).

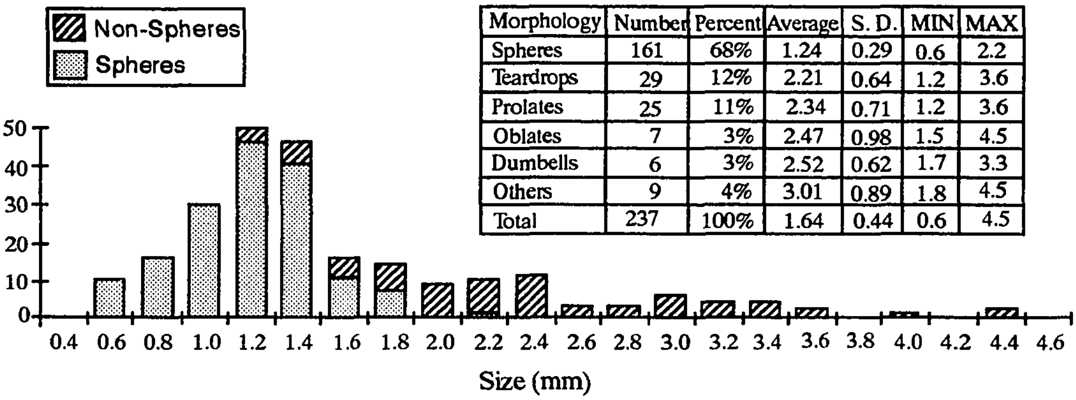
Polished sections of the bulk sedimentary rock and picked individual microtektite pseudomorphs were examined with transmitted and reflected light, and later by electron microscopy. All microtektite pseudomorphs have an external clay layer that is finely laminated parallel to the external surface. In some instances this clay layer is partially mammillary in habit, and in some pseudomorphs the entire interior is a network of mammillary clay spheres. Late calcite cement fills the remaining volume of the pseudomorphs typically forming large single crystals (Figure 14).

Clays apparently coated the cavities that formed as microtektite glass was dissolved during diagenesis of the host sediment. At least three clay types formed during diagenesis: 1) An impure smectite-oxide mixture is often the outside layer. The oxides include abundant TiO_2, but also likely oxides of iron; 2) A kaolinite layer formed and during periods of desiccation or chemical change pealed away from the pseudomorph walls to form a geopedal fill to the hollow spheres. 3) An oxide-free smectite seems to be the last clay to form.

Several hundred quartz grains were examined in thin section and over a thousand quartz grains were examined in grain mounts, but none displayed shock lamella. These thin sections and grain mounts were also examined for fresh glass, but again without success. Finally, the magnetic fraction from the sand and silt-sized washed material was examined in grain mounts and with SEM-EDS. No unusual spinel morphologies or compositions were observed.

COMPOSITION AND MINERALOGY OF CLAY PSEUDOMORPHS

Several grams of clay pseudomorphs were hand-picked and gently crushed for an x-ray diffraction study. Four oriented, clay-sized splits were examined: air-dried,



Morphology	Number	Percent	Average	S. D.	MIN	MAX
Spheres	161	68%	1.24	0.29	0.6	2.2
Teardrops	29	12%	2.21	0.64	1.2	3.6
Prolates	25	11%	2.34	0.71	1.2	3.6
Oblates	7	3%	2.47	0.98	1.5	4.5
Dumbells	6	3%	2.52	0.62	1.7	3.3
Others	9	4%	3.01	0.89	1.8	4.5
Total	237	100%	1.64	0.44	0.6	4.5

Figure 13 Morphology and size distribution of the tektite pseudomorphs, based on measurements of 237 hand-picked, whole particles.

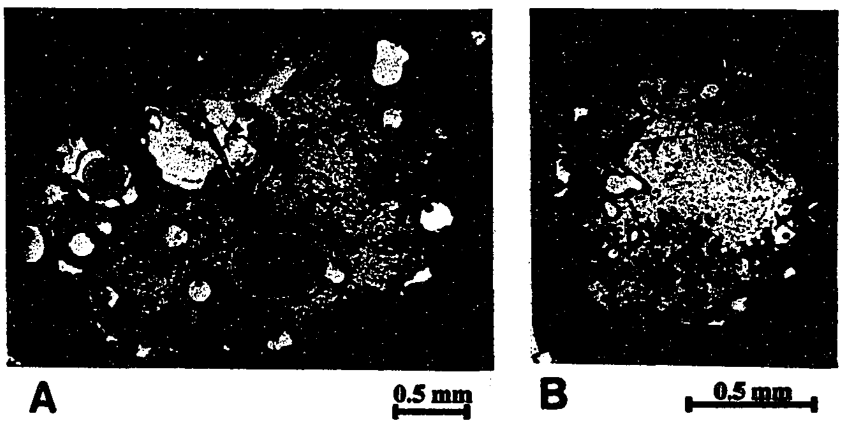


Figure 14 Polished-section photomicrographs of the pseudomorphs. A: Prolate spheroidal pseudomorph is 3.3 mm in longest dimension. A clay external layer is about 0.13 mm thick, composed of isotropic red-brown smectite and oxides. Numerous smaller clay-lined spherical cavities are contained within the pseudomorph. A single clear to drusy calcite crystal fills the remainder of the pseudomorph. B: Spheroidal pseudomorph with diameter of 1.8 mm. The exterior clay layer is finely crystalline and internally laminated. It is composed of red-brown smectite and oxide. A single clear calcite crystal fills the interior of the pseudomorph. The lower half of the pseudomorph also contains loosely packed 10-20 micron-sized flakes of smectite and kaolinite in a geopedal arrangement. (These features suggest that the tektite glass was initially dissolved with multiple generations of clay deposited on the wall of the hollow spheres and finally filled by calcite. Thus, the external features of the pseudomorphs faithfully reflect those of the original microtektite, but internal features represent only post-depositional, diagenetic events.)

glycolated, 300° C, and 550° C. These confirmed that the clays present were predominately well-crystallized smectites with minor kaolinite.

Clay pseudomorphs were imaged using back-scattered electrons (BSE) to evaluate compositional variations within individuals before point x-ray analyses were made. All pseudomorphs are finely zoned, with 2-5 mm thick laminae parallel to the external surface. Brighter BSE laminae are smectites dominated by Fe and Mg in octahedral sites. Darker laminae are smectites with dominant Al in octahedral sites. Titanium was also highly variable within the clays, and in some instances was clearly present as a dispersed submicron-sized oxide phase. Clays were also analyzed from internal spherical cavities within microtektite pseudomorphs. These generally have compositions similar to those of the clays of the external rims. A small number of these clays are nearly pure kaolinite. Isolated clay flakes are also found within the microtektites pseudomorphs, in several instances as geopedal fill encapsulated by subsequent calcite cement (Figure 14). Although similar to smectite pseudomorphs after microtektites found in Haiti and the western Atlantic, these differ in their low potassium contents. In most analyses calcium is the major interlayer cation. The clays of the Shell Creek microtektite pseudomorphs are distinctive, and whereas they cannot be used to confirm an andesitic composition similar the Haiti glasses, they are unlike other sedimentary clays in the sequence and suggest alteration from Mg- and Fe-bearing silicate glasses of probable impact origin.

DISCUSSION AND CONCLUSIONS

We deduce that the pseudomorphs from Shell Creek are alteration products of impact ejecta, formed at the end of Cretaceous. They are similar to tektites and tektite pseudomorphs found in the Gulf and Caribbean basins. Examination of Shell Creek samples for additional evidence to support the impact hypothesis, i.e., shocked quartz grains, relic tektite glass and the presence of minuscule grains of spinel, has turned out negative. Therefore the distinct morphologies of splash forms is the sole, but strong evidence that these objects represent impact ejecta. The size distribution of the spherules is also consistent with other documented K-T microtektite layers. The intensely weathered nature of the outcrop is believed to account for the fact that no tektite glass has been recovered.

We reject the contention of Stinnesbeck and others (1993) that similar spherules found in northeastern Mexico are diagenetic in origin. The Alabama microtektite pseudomorphs have similar features: extreme alteration, secondary infilling by smectite and calcite, geopedal fills. These are all a consequence of the inherent solubility of tektite glass in subaerial or shallow marine environments (Glass, 1984). The large fluence and average microtektite size from the K-T boundary in Alabama is further support for a very large meteorite impact at the end of the Cretaceous, at a location proxial to the northern Gulf of Mexico Basin.

REFERENCES TO CHAPTER III

Alvarez, W., Smit, J., and others, 1992, Proximal impact deposits at the Cretaceous-Tertiary boundary in the Gulf Of Mexico: A restudy of DSDP Leg 77 Sites 536 and 540: Geology, 20, 697-700.

Glass, B. P., 1984, Solution of naturally-occurring glasses in the geological environment: Journal of Non-Crystalline Solids, 67, 256-286.

Habib, D., Moshkovitz, S. and Kramer, C., 1992, Dinoflagellate and calcareous nannofossil response to sea-level change in Cretaceous-Tertiary boundary sections: Geology (Boulder), 20(2), 165-168.

Hildebrand, A. R., Penfield, G. T., Kring, D. A., Pilkington, M., Camargo Z., A., Jacobsen, S. B. and Boynton, W. V., 1991, Chicxulub crater: A possible Cretaceous/Tertiary boundary impact crater on the Yucatán Peninsula, Mexico: Geology, 19, 867-871.

Izett, G. A., 1991, Tektites in Cretaceous-Tertiary Boundary Rocks on Haiti and Their Bearing on the Alvarez Impact Extinction Hypothesis: Journal of Geophysical Research, 96, No. E4, 20879-20905.

Izett, G. A., Maurrasse, F. J. M. R., Lichte, F. E., Meeker, G. P. and Bates, R., 1990, Tektites in Cretaceous-Tertiary boundary rocks on Haiti: U.S. Geological Survey Open-File Report, 90-635, 1-31.

Klaver, G. T., Kempen, T. M. G. v., Bianchi, F. R. and Gaast, S. J. v. d., 1993, Green Spherules as Indicators of the Cretaceous/Tertiary Boundary in Deep Sea Drilling Project Hole 603B: *in* Hinte, J. E. v., Wise, S. W., Jr. and al, e., eds., Initial Reports of Deep Sea Drilling Project: U.S. Government Printing Office, Washington D.C, 1039-1056.

LaMoreaux, P. E. and Toulmin, L. D., 1959, Geology and groundwater resources of Wilcox County, Alabama: Alabama Geological Survey County Report, 4, 280p.

Mancini, E. A., Tew, B. H. and Smith, C. C., 1989, Cretaceous-Tertiary contact, Mississippi and Alabama: Journal of Foraminiferal Research, 19, 93-104.

Maurrasse, F. J. M. R. and Sen, G., 1991, Impacts, tasunamis, and the Haitian Cretaceous-Tertiary boundary layer: Science, 252(5013), 1690-1693.

Montanari, A., 1991, Authigenesis of impact spheroids in the K-T boundary clay from Italy: Journal of Sedimentary Petrology, 61, 315-339.

Olsson, R. K. and Lui, C., 1992, A Biostratigraphically continuousn Cretaceous/Paleogene section at Millers Ferry, Alabama:Support for a Bolide Impact: Geological Society of America, Annual Meeting, Cincinnati, Ohio, A29

Penfield, G. T. and Camargo Z., A., 1981, Definition of a major igneous zone in the central Yucatán platform with aeromagnetics and gravity: Society of Exploration Geophysicists Technical Program, Abstracts and Biographies, 51, 37.

Pitakpaivan, K. and Hazel, J. E., 1992, Pseudomorphs of Microtektites at the Cretaceous/Tertiary Boundary in Alabama and Mississippi: Geological Society of America Abstracts with Programs, 24(7), A361.

Pitakpaivan, K. and Hazel, J. E., 1994, Ostracodes and chronostratigraphic position of the Upper Cretaceous Arkadelphia Formation of Arkansas: Journal of Paleontology, 68, 111-122.

Pope, K. O., Ocampo, A. C. and Duller, C. E., 1991, Mexican site for K/T impact crater: Nature, 351, 105.

Roth, P. H., 1978, Cretaceous nannoplankton biostratigraphy and oceanography of the Northwester Atlantic Ocean: Initial Rep. Deep Sea Drill Proj., 44, 731-759.

Russell, E. E., Keady, D. M., Mancini, E. E. and Smith, C. C., 1983, Upper Cretaceous lithostratigraphy and biostratigraphy in northeast Mississippi, southwest Alabama, and northwest Alabama, shelf chalks and clastics: Field Trip Guidebook for 1983 Spring Field Trip of Gulf Coast Section, Society of Economic Paleontologists and Mineralogists, 72 p.

Smit, J., Montanari, A., and others, 1992, Tektite-bearing, deep-water clastic unit at the Cretaceous-Tertiary boundary in northeastern Mexico: Geology, 20, 99-103.

Smith, C. C. and Mancini, E. E., 1983, Calcareous nannofossil and planktonic foraminiferal biostratigraphy: *in* Russell, E. E., Keady, D.M., Mancini, E.E., and Smith, C.C, eds., Calcareous nannofossil and planktonic foraminiferal biostratigraphy: Upper Cretaceous lithostratigraphy and biostratigraphy in northeast Mississippi, southwest Alabama, and northwest Alabama, shelf chalks and clastics: Field Trip Guidebook for 1983 Spring Field Trip of Gulf Coast Section, Society of Economic Paleontologists and Mineralogists, 16-28.

Sohl, N. F. and Koch, C., 1986, Molluscan biostratigraphy and biofacies of the Huastator bilira assemblage zone (Maastrichtian) of the East Gulf Coastal Plain: *in* Reinhardt, J., eds., Stratigraphy and sedimentology of continental, nearshore, and marine Cretaceous sediments of the Eastern Gulf Coastal Plain, Field Trip Guide, SEPM-AAPG Annual Meeting, 45-56.

Stinnesbeck, W., Barbarin, J. M., and others, 1993, Deposition of channel deposits near the Cretaceous-Tertiary boundary in northeastern Mexico: Catastrophic or "normal" sedimentary deposits?: Geology, 21, 799-802.

CHAPTER IV

OSTRACODA OF THE HAUSTATOR BILIRA ASSEMBLAGE ZONE (MAASTRICHTIAN) OF THE EASTERN GULF COASTAL PLAIN: APPLICATION TO BIOSTRATIGRAPHIC AND PALEOENVIRONMENTAL INTERPRETATION

INTRODUCTION

Despite their commonness in Upper Cretaceous sediments and their usefulness in solving geologic problems, Upper Cretaceous ostracodes of North America have not been extensively studied. There are no references that are equivalent to the stratigraphical index of the British Ostracoda (Bate and Robinson 1978) or the french ostracode atlas (Oertli, 1985). The closest to these is the Coniacian-Maastrichtian contribution of Hazel and Brouwers (1982). Existing literature on North American Upper Cretaceous ostracodes mostly deal with taxonomy, which includes the excellent monograph of C. I. Alexander (1929) on the ostracodes of Texas, as well as his subsequent papers (Alexander, 1933; 1934; 1936). Other significant contributions are Berry (1925), Israelsky (1929), Jennings (1936), Butler and Jones (1957), Holden (1964), Crane (1965), Brouwers and Hazel (1978), and Smith (1978). The compilation by Howe and Laurencich (1958) is extensive, but not up to date. The exception as mentioned above is an important work by Hazel and Brouwers (1982) who established a key bio- and chronostratigraphic framework for Upper Cretaceous ostracodes of the Atlantic and Gulf Coastal Plain. In the last decade the application of ostracodes to stratigraphy has only moderately increased (Chimene and Maddocks, 1984; Maddocks, 1985; Pitakpaivan and Hazel, 1994; Puckett 1994). The uppermost stage of the Cretaceous, the Maastrichtian, has received the least attention (see Pitakpaivan and Hazel, 1994).

Ostracodes, like most other benthic organisms, are very useful in paleoenvironmental interpretation, but limited in intercontinental correlation. However, they are an important biostratigraphic tool within major regions. The area and stratigraphic interval under investigation is in the eastern Gulf Coast part of the Atlantic and Gulf Coastal Province of North America (Murray, 1961), which is a major geologic and zoogeographic province. The stratigraphic interval is within the molluscan

Haustator bilira Assemblage Zone of Sohl (1977). This biostratigraphic unit can be traced from Texas to New Jersey. In the eastern Gulf Coast the Haustator bilira assemblage has been identified from the Chattahoochee River area of eastern Alabama and western Georgia to Mississippi and Tennessee (Sohl and Koch, 1986; Sohl and Owens, 1990).

The purpose of this paper is to 1) describe the distribution of ostracodes in the Maastrichtian rock units assigned to the molluscan Haustator bilira Assemblage Zone, 2) determine any corresponding trends between ostracode faunal changes and lithologic changes, 3) assess their usefulness in biostratigraphy and paleoecology, and evaluate the ostracode Platycosta lixula and Veenia parallelopora Zones for their applicability to the uppermost Cretaceous units throughout this region.

GENERAL STRATIGRAPHY

In the eastern Gulf Coastal Plain of North America the outcrop belt of the uppermost Maastrichtian strata consists of the Providence Formation of western Georgia and eastern Alabama, the Prairie Bluff Formation of Alabama and Mississippi, and Owl Creek Formation of Mississippi and Tennessee. The coeval Prairie Bluff, Providence and Owl Creek rest disconformably upon the Ripley Formation, and are in turn overlain by the Paleocene Clayton Formation. The outcrops exhibit a lithologic change from the siliciclastic dominated Providence in western Georgia and eastern Alabama to the carbonate-dominated facies of the Prairie Bluff in central and western Alabama and northeastern Mississippi, and then to clastics again in northeast Mississippi in the form of the Owl Creek (Figure 15). The facies changes are the result of the existing outcrop belt being oblique to the original Late Cretaceous depositional strike (Sohl and Koch, 1986). These marine shelfal deposits were the result of a late Maastrichtian transgression (Sohl and others, 1991).

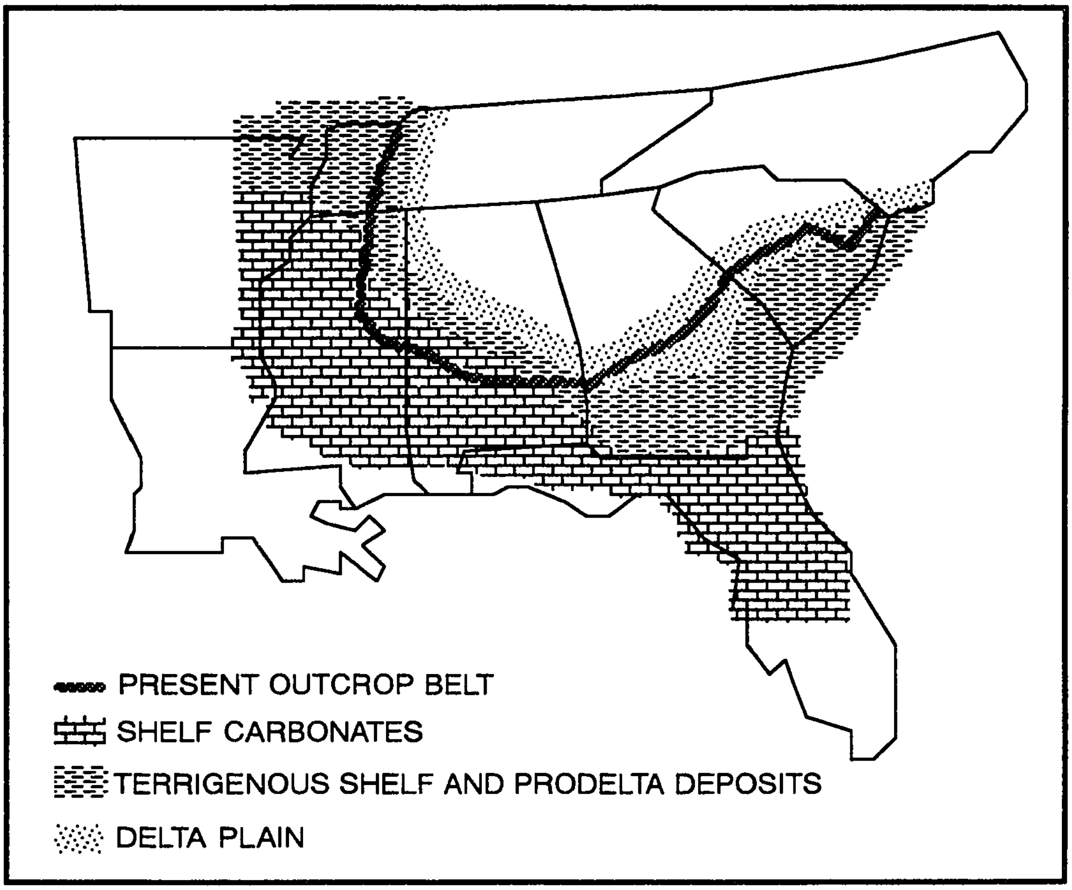


Figure 15 Reconstruction of the relationships of the upper Maastrichtian lithofacies units of the eastern Gulf Coastal Plain. (Modified from Sohl and Koch, 1986)

The calcareous Prairie Bluff is exposed from eastern Alabama to northeast Mississippi and varies in thickness from 4 to 38 meters (Sohl and others, 1991). It is locally absent in parts of Dallas, Wilcox and Marengo Counties, Alabama due to post-depositional erosion (LaMoreaux and Toulmin, 1959; Copeland, 1968). The Prairie Bluff Formation is generally made up of dense white to bluish white chalky marl and glauconitic sandy marl (Russell and others, 1983; Mancini and others, 1989; Sohl and others, 1991). It has been referred to as Prairie Bluff Chalk even though it does not consist of chalk in a strict sense. The basal part of the Prairie Bluff generally contains various amounts of coarse quartz sand, glauconite, phosphatic fossil molds and pebbles. The upper part begins to merge laterally into the siliciclastics of the Providence Formation beginning in the western part of Lowndes County, Alabama. This results in a gradual thinning of the chalk tongue. To the west, the Prairie Bluff extends into northeast Mississippi where in Pontotoc and Union Counties it becomes more argillaceous and merges into the glauconitic, silty, clay rich marine sands of the Owl Creek Formation. The Owl Creek extends through Tippah County in Mississippi into Tennessee, becoming less calcareous northward. At few places, about a foot of hard sandy limestone has been observed in the Owl Creek (Stephenson and Monroe, 1940; Sohl, 1960).

The Providence Formation is generally made up of unfossiliferous shallow water deposits and highly fossiliferous offshore marine sandy clay and sand (Stephenson and Monroe, 1940; Donovan, 1986). Within the Chattahoochee River area, between the base of the Providence and the erosional unconformity at the top of the Ripley Formation, lies a distinct informal lithologic unit called the Alexander's Landing beds of the Providence Formation. These beds crop out locally and have been interpreted as incised valley fill (Donovan, 1986). The Alexander's Landing beds have been recognized by Sohl and Koch (1986) to contain a fauna of the lower part of the

Haustator bilira Assemblage Zone, which is also characteristic of the Chiwapa Sandstone Member of the Ripley Formation in northeast Mississippi. The Owl Creek, Prairie Bluff, and Providence Formations have been assigned to the middle to late middle Maastrichtian by planktonic foraminiferal workers (Smith and Mancini, 1983; Russell and others, 1983; Mancini and others, 1989). However, recent studies using calcareous nannofossil and planktonic foraminifera indicated late Maastrichtian age for the Prairie Bluff in a few places in Alabama (Olsson and Lui, 1992; Olsson and Lui, 1993; Habib and others, 1992; Pitakpaivan and Hazel, 1994).

MATERIALS AND METHODS

In the area of study, a total of 105 rock samples were collected and processed for ostracodes. Samples were treated by breaking them gently into pea-sized pieces with a rock hammer. These then were soaked in a dilute solution of sodium bicarbonate. After wet sieving through a 74 micron screen (#200 sieve), they were dried in an oven overnight at about 50° C. The samples were split, sieved on a 177-micron screen (#80 sieve), and then randomly picked to obtain at least 500 specimens including both adults and juveniles, males and females, and single valves and whole carapaces. A single valve was counted as one specimen; one carapace was counted as two. Thus the number of individual ostracode organisms represented is less than the number of specimens recorded. Among these samples 46 samples containing at least 100 specimens were selected for cluster analysis in order to ascertain which samples are most similar to each other based on the contained assemblage. Any species representing less than 1% of the total was considered as rare and was not used in the cluster analysis. The distribution of such rare species could not be confidently determined (see Buzas and others, 1982). The SYSTAT (System for Statistics) package, version 5.2.1 (Wilkinson and others, 1992), was used to perform an average linkage Q-mode cluster analysis using the Pearson correlation coefficient on a Macintosh IIsi microcomputer.

Then the samples were compared on their species content, R-mode analysis, to see which taxa influenced the groupings of samples.

The percentage of samples in which a species occurs in each biofacies can be called the sample constancy (C) and can be calculated to determined the relative contribution of that species to a certain biofacies. Then the percentages can be used to calculate the biofacies fidelity of a species for a biofacies using the following equation for Hazel (1970)

$$BF_{j,i} = \frac{P_i}{\sum_{i=1}^{p} P_i} \times 10$$

where P_i is the percentage of occurrences of a species in a particular biofacies unit i (i = 1,2,3,4,....p) and j is the species (j = a,b,c,d....n).

A simple measure of the species diversity is S, the number of species observed in a sample (Gibson and Buzas, 1973). It is therefore dependent on sample size. The most widely used diversity indices is the Shannon-Wiener information function, H. It is dependent not only on the number of species, but also on the relatives abundances of species (Gibson and Buzas, 1973). It is given by the equation:

$$H = -\Sigma \ p_i \times \ln p_i$$

where p_i is the proportion of the ith species (MacArthur and MacArthur, 1961; Pielou, 1966; Gibson and Buzas, 1973).

OSTRACODE STRATIGRAPHY AND DISTRIBUTION

A total of 42,304 ostracode specimens from the 105 rock samples, representing 38 genera and 130 species or undifferentiated species groups were examined. The unornamented valves and indistinctive shapes of the platycopid genus Cytherella presented difficulties in determining how many species are present. Because of this, the Cytherella are grouped together under Cytherella spp. The stratigraphic and geographic distribution of the samples is shown in Figure 16. Of these samples, the 38 best samples from eight designated geographic areas that represent variations in lithofacies were analyzed for biogeographic distribution patterns. The eight areas consist of the clastic-dominated units in the Chattahoochee River area, eastern Alabama and northeast Mississippi; lithically transitional areas in eastern Alabama and northeastern Mississippi where clastic-dominated facies merge into a carbonate-dominated facies and vice versa; and the carbonate-dominated facies in central and western Alabama and northeastern Mississippi. Tables 4 and 5 list the relative abundances of the genera and species in each area. The lithofacies used in the two tables are derived from various sources, particularly Sohl and Koch (1986).

Samples from the Providence Sand of the Chattahoochee River region are dominated by a single species, Haplocytheridea everetti, and have the lowest average number of species per sample (16) and a diversity index of only 1.78. These samples are also distinguished by five common species, Antibythocypris minuta, Anticythereis sp 6, Brachycythere rhomboidalis, Cytherella spp. and Fissocarinocythere pidgeoni. This major component is very distinct suggesting a difference in environmental conditions. Samples from the Providence Sand in eastern Alabama, however, are dominated by Haplocytheridea renfroensis. The average number of species in a sample (23 species) and the diversity index (2.10) in this area are also low. Brachycythere ovata, Brachycythere rhomboidalis, Cytherella spp., Haplocytheridea everetti and Loxoconcha cretacea are the common species. These major components show a close affinity to those of the adjacent Prairie Bluff.

The Prairie Bluff samples from eastern Alabama to northeast Mississippi are dominated by Cytherella spp., with the exception of those from northeast Mississippi where Bairdoppilata magna is also a dominant form. Throughout the area samples from the Prairie Bluff have an average number of species per sample between 26 to 40 species, and a diversity index of between 2.62 to 2.80. These assemblages also have

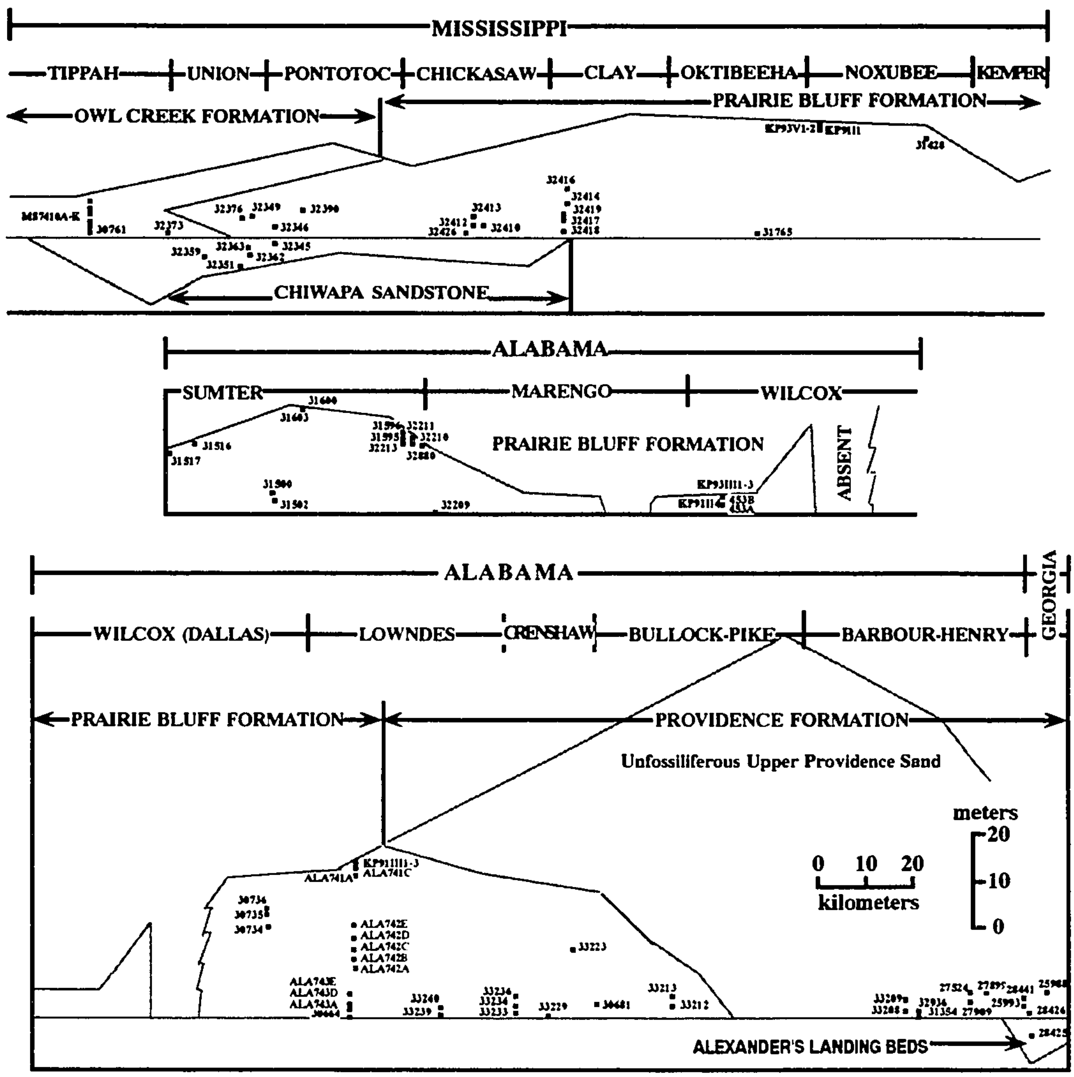


Figure 16 Stratigraphic and geographic position of samples used in this study. Lithostratigraphic relationships modified from Sohl & Koch (1986) and Sohl (1960). Gray solid lines are lithologic boundaries.

Table 4 Relative abundance of ostracode genera in the studied area (● > 15%, ⊙ = 5-15 %, ○ = 1-5%, • < 1%). Note that Bythoceratina and Cuneoceratina were grouped into "Monoceratina".

Genus	northeast Mississippi			western - central Alabama		eastern Alabama-western Georgia		
	clastic-dominated units	carbonate-dominated units					clastic-dominated units	
Alatacythere	○	•	○	○	○	—	—	—
Amphicytherura	⊙	⊙	○	•	○	○	•	—
Antibythocypris	●	●	⊙	○	⊙	●	⊙	●
Anticythereis	⊙	⊙	○	—	○	○	•	⊙
Argilloecia	—	○	•	•	•	○	•	—
Ascetoleberis	○	•	○	○	○	—	•	—
Aversovalva	○	•	—	•	•	○	—	—
Bairdoppilata	⊙	⊙	●	⊙	⊙	○	○	—
Brachycythere	●	●	●	●	●	⊙	●	●
Bythocypris	○	•	○	○	•	—	•	—
Curfsina	⊙	○	○	○	⊙	•	○	—
Cushmanidea	○	○	—	—	•	○	•	—
Cytherella	●	●	●	●	●	●	⊙	⊙
Cytherelloidea	○	⊙	⊙	⊙	⊙	○	•	—
Cytheromorpha	—	—	—	—	—	•	•	—
Cytheropteron	•	○	○	○	○	•	—	○
Eocytheropteron	—	—	—	—	—	⊙	—	—
Escharacytheridea	○	○	⊙	⊙	⊙	—	○	•
Eucythere	—	•	•	•	•	—	—	—
Eucytherura	—	—	—	•	•	—	—	—
Fissocarinocythere	○	○	○	○	○	○	•	⊙
Haplocytheridea	⊙	⊙	●	●	●	⊙	●	●
Krithe	○	•	○	○	○	○	•	—
Limburgina	○	•	○	•	○	—	•	—
Loxoconcha	○	•	○	○	○	●	⊙	○
Macrocypris	—	—	•	○	•	—	•	—
"Monoceratina"	—	—	○	○	•	—	—	—
Orthonotacythere	○	•	•	•	○	—	•	—
Paracypris	—	•	•	○	•	—	—	—
"Planileberis"	—	•	○	○	•	—	—	—
Platycosta	○	○	•	○	○	○	•	—
Polylophus	—	—	—	—	•	○	•	—
Pterygocythere	•	•	○	○	•	—	—	—
Soudanella	—	•	—	—	•	○	•	—
Sphaeroleberis	—	—	•	•	—	—	—	—
Veenia	—	○	⊙	○	○	—	—	—
Xestoleberis	○	○	○	⊙	⊙	⊙	○	—

Table 5 Relative abundance of ostracode species in the studied area (● > 15%, ⊙ = 5-15%, O = 1-5%, • < 1%)

Species	northeast Mississippi			western - central Alabama		eastern Alabama- western Georgia		
	clastic-dominated units	carbonate-dominated units					clastic-dominated units	
Alatacythere aff. A. serrata	O	•	O	O	O	—	—	—
Alatacythere ponderosana	—	—	•	•	•	—	—	—
Amphicytherura curta	⊙	⊙	O	•	O	O	•	—
Antibythocypris crassa	O	⊙	O	—	•	O	—	O
Antibythocypris elongata	—	—	—	—	—	O	—	•
Antibythocypris fabaformis	O	O	•	—	•	O	•	•
Antibythocypris gooberi	O	⊙	⊙	O	O	•	O	•
Antibythocypris macropora	—	—	—	—	—	O	—	—
Antibythocypris minuta	⊙	⊙	O	•	•	O	O	⊙
Antibythocypris multilira	O	O	—	—	•	⊙	—	O
Antibythocypris pataulensis	—	•	—	—	•	—	—	•
Antibythocypris phaseolites	O	O	—	—	—	O	—	—
Antibythocypris trisulcata	O	•	—	—	•	—	—	—
Anticythereis sp. 2	—	•	—	—	—	—	—	—
Anticythereis sp. 3	—	O	—	—	•	—	—	—
Anticythereis sp. 4	O	O	—	—	•	—	—	—
Anticythereis sp. 5	—	—	—	—	—	•	—	—
Anticythereis sp. 6	—	—	—	—	—	O	—	⊙
Anticythereis sp. 7	O	O	—	—	•	—	—	—
Anticythereis sp. 8	—	—	—	—	—	—	—	O
Anticythereis sp. 9	—	—	—	—	—	—	—	O
Anticythereis sp. 10	—	—	•	—	—	—	—	—
Anticythereis sp. 11	—	O	—	—	—	—	—	—
Anticythereis sp. 12	O	•	—	—	—	—	—	—
Anticythereis sp. 13	—	—	•	—	—	—	—	—
Anticythereis sp. 15	—	•	—	—	—	—	—	O
Anticythereis sp. 16	•	O	—	—	—	—	—	—
Anticythereis sp. 17	•	O	—	—	•	—	—	•
Anticythereis sp. 20	—	—	—	—	—	—	•	—
Anticythereis copelandi	O	•	—	—	•	•	—	—
Argilloecia sp. 1	—	O	•	•	•	O	•	—
Argilloecia sp. 2	—	•	•	•	•	—	—	—
Ascetoleberis hazardi	O	•	O	O	O	—	•	—
Aversovalva fossata s.l.	O	•	—	•	•	O	—	—

table con'd.

Species	northeast Mississippi		western - central Alabama				eastern Alabama-western Georgia	
	clastic-dominated units ←		carbonate-dominated units			→	clastic-dominated units	
Bairdoppilata magna	⊙	○	●	⊙	○	○	•	–
Bairdia sp. 1	–	–	–	–	•	–	•	–
Bairdia sp. 2	–	•	–	•	–	–	–	–
Bairdia sp. 3	–	○	–	–	•	–	•	–
Brachycythere foraminosa s.l.	⊙	⊙	○	○	⊙	○	•	–
Brachycythere porosa	○	–	–	–	–	–	–	–
Brachycythere ledaforma	○	○	○	○	⊙	–	–	–
Brachycythere ovata	⊙	⊙	⊙	⊙	⊙	⊙	⊙	○
Brachycythere rhomboidalis	○	○	⊙	○	⊙	○	⊙	⊙
Brachycythere sp. B	–	–	•	–	–	–	–	–
Bythoceratina aff. B. acanthoptera	–	–	•	–	•	–	–	–
Bythoceratina aff. B. umbonata	–	–	•	•	–	–	–	–
Bythocypris sp. 1	–	–	–	•	–	–	–	–
Bythocypris sp. 2	–	–	–	○	–	–	–	–
Bythocypris sp. 3	○	–	•	–	•	–	–	–
Bythocypris windhami	–	•	○	•	•	–	•	–
Cuneoceratina aff. C. pedata	–	–	•	○	–	–	–	–
Cuneoceratina aff. C. prothroensis	–	–	–	•	–	–	–	–
Cuneoceratina prothroensis	–	–	•	•	–	–	–	–
Curfsina communis	⊙	○	○	○	⊙	•	○	–
Cushmanidea sp. 1	–	–	–	–	–	•	–	–
Cushmanidea sp. 2	–	–	–	–	–	○	–	–
Cushmanidea sp. 3	–	–	–	–	–	–	•	–
Cushmanidea sp. 4	–	•	–	–	–	–	–	–
Cushmanidea sp. 5	○	○	–	–	•	–	•	–
Cytherella spp.	●	●	●	●	●	●	⊙	⊙
Cytherelloidea aff. C. austinenesis	–	–	–	•	–	–	–	–
Cytherelloidea aff. C. spilaria	○	–	–	•	–	–	–	–
Cytherelloidea aff. C. tolletensis	–	–	–	–	–	–	•	–
Cytherelloidea austinenesis	–	–	○	–	○	–	–	–
Cytherelloidea bicosta s.l.	○	○	○	○	○	○	–	–
Cytherelloidea crafti	–	–	○	○	○	–	–	–
Cytherelloidea inflata	–	–	•	•	•	–	–	–
Cytheromorpha cf. C. arbenzi	–	–	–	–	–	•	–	–
Cytheromorpha cf. C. pittsi	–	–	–	–	–	–	•	–
Cytheropteron castorensis	–	•	•	•	•	•	–	○

table con'd.

Species	northeast Mississippi		western - central Alabama			eastern Alabama- western Georgia		
	clastic-dominated units ←		carbonate-dominated units					→ clastic-dominated units
Cytheropteron cf. C. type A of Smith	•	•	–	–	•	–	–	–
Cytheropteron coryelli	–	–	•	•	•	–	–	–
Cytheropteron navarroense	–	•	○	•	•	–	–	–
Cytheropteron sp. A	–	–	–	–	•	–	–	–
Eocytheropteron striatum	–	–	–	–	–	⊙	–	–
Escharacytheridea magnamandibulata	○	○	–	–	•	–	•	•
Escharacytheridea micropunctata	○	•	○	○	⊙	–	•	–
Escharacytheridea pinochii	○	•	○	○	○	–	•	–
Eucythere aff. E. brightseatensis	–	–	•	–	–	–	–	–
Eucythere sohli	–	•	–	•	•	–	–	–
Eucytherura aff. E. reticulata	–	–	–	•	•	–	–	–
Fissocarinocythere huntensis	○	○	○	○	○	–	–	–
Fissocarinocythere pidgeoni	–	–	•	–	•	○	•	⊙
Haplocytheridea bruceclarki	⊙	⊙	⊙	○	○	–	–	–
Haplocytheridea everetti	–	–	⊙	○	⊙	⊙	⊙	●
Haplocytheridea globosa	–	–	○	○	○	○	–	–
Haplocytheridea renfroensis	○	–	○	⊙	⊙	–	●	–
Haplocytheridea renfroensis (large)	–	–	○	–	•	–	–	–
Krithe whitecliffsensis	○	•	○	○	○	○	•	–
Limburgina foresterae	○	•	○	•	○	–	•	–
Loxoconcha clinocosta	–	–	–	•	•	⊙	•	•
Loxoconcha cretacea	–	–	–	○	•	–	⊙	•
Loxoconcha erecticosta	–	•	–	–	•	○	○	–
Loxoconcha fletcheri	–	•	–	•	•	–	–	–
Loxoconcha minardi	–	–	–	–	–	•	–	○
Loxoconcha plegma	–	–	–	–	•	–	•	–
Loxoconcha renfroensis	○	–	–	–	–	–	–	–
Loxoconcha sp. B	–	–	–	–	–	○	–	–
Loxoconcha striata	○	–	○	–	•	•	–	–
Macrocypris sp.1	–	–	•	•	–	–	•	–
Macrocypris sp.2	–	–	•	–	–	–	–	–
Macrocypris sp. 3	–	–	–	–	•	–	–	–
"Monoceratina" aff. "M." nitida	–	–	•	–	–	–	–	–
"Monoceratina" sp. A	–	–	•	•	–	–	–	–
"Monoceratina" sp. B	–	–	–	•	–	–	–	–
"Monoceratina" sp. C	–	–	–	•	•	–	–	–

table con'd.

northeast Mississippi | western - central Alabama | eastern Alabama- western Georgia

clastic- dominated units ⟵ carbonate-dominated units ⟶ clastic- dominated units

Species								
"Monoceratina" sp. D	–	–	–	•	–	–	–	–
"Monoceratina" sp. E	–	–	–	•	•	–	–	–
Orthonotacythere hannai	O	•	•	•	O	–	•	–
Paracypris sp. 1	–	•	•	–	–	–	–	–
Paracypris sp. 2	–	–	–	•	•	–	–	–
Paracypris sp. 3	–	–	–	O	•	–	–	–
Paracypris sp. 4	–	–	•	•	–	–	–	–
"Planileberis" cf. P. costatana	–	•	O	O	•	–	–	–
Platycosta lixula	O	O	•	O	O	O	•	–
Polylophus asper	–	–	–	–	•	O	•	–
Pterygocythere saratogana	•	•	O	O	•	–	–	–
Soudanella parallelopora	–	•	–	–	•	O	•	–
Soudanella sp. B	–	–	–	–	–	•	–	–
Sphaeroleberis pseudoconcentrica	–	–	•	•	–	–	–	–
Veenia adkinsi	–	O	O	O	•	–	–	–
Veenia arachoides	–	–	O	–	O	–	–	–
Veenia parallelopora	–	–	O	O	•	–	–	–
Xestoleberis opina	O	•	O	O	O	⊙	•	–
Xestoleberis seminulata	–	•	•	O	O	O	•	–
Xestoleberis sp. 1	–	–	–	–	•	–	–	–
Xestoleberis sp. 2	–	–	•	•	–	–	–	–
Xestoleberis sp. 3	–	–	–	•	•	–	–	–
Xestoleberis sp. 4	–	–	–	–	–	O	•	–

Brachycythere ovata as one of the common species. In the Pike and Bullock Counties area of eastern Alabama, samples of the Prairie Bluff have five other species that are common. These are Antibythocypris multilira, Eocytheropteron striatum, Haplocytheridea everetti, Loxoconcha clinocosta and Xestoleberis opina. This composition is distinct from the common component of the Prairie Bluff westward. In central Alabama the common component consists of Brachycythere foraminosa s.l., Brachycythere ledaforma, Brachycythere rhomboidalis, Curfsina communis, Escharacytheridea micropunctata, Haplocytheridea everetti and Haplocytheridea renfroensis. In western Alabama the common component includes only Haplocytheridea renfroensis plus Bairdoppilata magna. A similar component is also common in the Prairie Bluff of northeast Mississippi and includes Antibythocypris gooberi, Brachycythere rhomboidalis, Haplocytheridea bruceclarki, and Haplocytheridea everetti.

To the northwest, in Pontotoc and Union Counties, Mississippi where the Prairie Bluff becomes less calcareous, the common component is slightly different and includes Amphicytherura curta, Antibythocypris crassa, Antibythocypris gooberi, Antibythocypris minuta, Brachycythere foraminosa s.l., and Haplocytheridea bruceclarki. Samples from the Owl Creek Formation have an average number of species of 19 and the diversity index is 2.50, both of which are relatively low. The Owl Creek samples also contain Cytherella spp. in conspicuous abundance and seven common species, Amphicytherura curta, Antibythocypris minuta, Bairdoppilata magna, Brachycythere foraminosa s.l., Brachycythere ovata, Curfsina communis, and Haplocytheridea bruceclarki. This assemblage is similar to that of the Prairie Bluff of Mississippi. Therefore, at a species level, ostracode abundance obviously responds to lithologic changes which in turn reflect changes in environmental condition. The ostracodes can be divided into five groups based on their occurrences in lithofacies

(Table 6). There are species that are common in clastic-dominated facies, but not in carbonate-dominated facies, and vice versa. On the other hand, there are species that are found exclusively in either clastic-dominated facies or carbonate-dominated facies. Further, there are species that are ubiquitous. The last group, therefore, represents taxa that are the most useful for interfacies correlation.

At the generic level, samples from the Providence Sand are dominated by Haplocytheridea and Brachycythere, but not Cytherella, which is the dominant taxon in samples from the rest of the study area. The Providence of the Chattahoochee River area is also dominated by Antibythocypris, which is also a characteristic genus of the Prairie Bluff of Pike and Bullock Counties, Alabama, and Pontotoc and Union Counties, Mississippi where the carbonates grade into sands. In contrast, the dominant genera of samples from the Prairie Bluff of eastern Alabama are Cytherella and Loxoconcha. The Prairie Bluff samples of Pontotoc and Union Counties, Mississippi, resemble the Owl Creek in having Brachycythere and Cytherella as another two dominant genera. A similar pattern is also found in samples from the Prairie Bluff of central and western Alabama and northeastern Mississippi where Brachycythere, Cytherella, and Haplocytheridea, instead of Antibythocypris, are the dominant genera. Besides these three genera, the Prairie Bluff samples in northeast Mississippi contain abundant Bairdoppilata. Table 7 summarizes the facies habitat preferences of ostracode genera.

On the basis of Q-mode cluster analysis, an additional relationship between the observed ostracode assemblages and lithologic facies becomes apparent. Figure 16 shows the distribution pattern of lithologic units. Figure 17 is a dendrogram grouping samples on the basis of taxonomic content. Table 8 summarizes the clusters of samples. The cluster analysis separated the samples into four major groups. Cluster #1 represents samples of the clastic-dominated units of the Providence Sand of the

Chattahoochee River area; whereas cluster #2 represents those samples from the Providence Sand of other localities in eastern Alabama. Cluster #3 represents samples from the Prairie Bluff of eastern Alabama, western Alabama and northeastern Mississippi. Two major subclusters can be recognized in cluster #3 (Figure 17). The first subcluster represents samples from the upper part of the Prairie Bluff of western Alabama and northeastern Mississippi, with the exception of two samples from central Alabama. The second subcluster represents samples from the basal or lower part of the Prairie Bluff, with the exception of three samples from the upper part. The rest of the subcluster represents samples of the Prairie Bluff that are clayey sand or sandy clay, and one sample from the Owl Creek. Cluster #4 represents samples of Owl Creek Formation and the Chiwapa Member of Ripley Formation. In general the sample groupings correspond to major lithologic facies.

To evaluate which species were principally responsible for the groupings of samples, species were compared based on their occurrences in samples (R-mode). Figure 18 is a dendrogram of species grouping. Full names of species that were abbreviated in the dendrogram are given in Table 9. Species were separated into five groups, which were summarized in Table 10. Cluster A represents characteristic species of the Providence Sand samples of the Chattahoochee River area, and therefore is responsible for grouping samples in Cluster #1. Cluster B represents species that characterized samples of Providence Sand of eastern Alabama which were grouped into Cluster #2. Cluster C represents characteristic species of Prairie Bluff samples of eastern and central Alabama. However, one sample of Owl Creek Formation was characterized by this group. Cluster D represents characteristic species of Owl Creek Formation and Chiwapa Member of the Ripley Formation, and thus is responsible for grouping samples in Cluster #4. This group of species, however also characterizes samples of basal or lower part of the Prairie Bluff of western Alabama and northeast

Table 6 List of five groups of ostracode species according to their difference in abundances in certain lithofacies.

Species commonly occur in		Species occur exclusively in		Species occur in both clastic-dominated and carbonate-dominated units
Clastic	Carboante	Clastic	Carbonate	
Amphicytherura curta	Alatacythere aff. A. serrata	Antibythocypris elongata	Anticythereis sp. 10	Antibythocypris gooberi
Antibythocypris crassa	Ascetoleberis hazardi	Antibythocypris phaseolites	Anticythereis sp. 13	Brachycythere foraminosa s.l.
Antibythocypris fabaformis	Bairdoppilata magna	Anticythereis sp. 6	Bythoceratina aff. B. umbonata	Brachycythere ovata
Antibythocypris minuta	Brachycythere ledaforma	Anticythereis sp. 8	Bythocypris sp. 1	Brachycythere rhomboidalis
Antibythocypris multilira	Bythocypris wihdhami	Anticythereis sp. 9	Bythocypris sp. 2	Curfsina communis
Antibythocypris pataulensis	Cytherelloidea crafti	Anticythereis sp. 12	Cuneoceratina aff. C. pedata	Cytherella spp.
Antibythocypris trisulcata	Cytherelloidea inflata	Anticythereis sp. 16	Cuneoceratina aff. C. prothroensis	Cytherelloidea bicosta s.l.
Anticythereis copelandi	Cytheropteron coryelli	Cushmanidea sp. 1	Cuneoceratina prothroensis	Cytheropteron castorensis
Aversovalva fossatum s.l.	Cytheropteron navarroense	Cushmanidea sp. 2	Macrocypris sp. 2	Escharacytheridea micropunctata
Escharacytheridea magnamadibulata	Eucythere sohli	Cushmanidea sp. 3	"Monoceratina" aff. "M." nitida	
	Eucytherura aff. reticulata	Cushmanidea sp. 4	"Monoceratina" sp. A	Escharacytheridea pinochii
Haplocytheridea everetti	Haplocytheridea bruceclarki	Cytheromorpha cf. C.arbenzi	"Monoceratina" sp. B	Fissocarinocythere huntensis
Haplocytheridea renfroensis	Haplocytheridea globosa	Cytheromorpha cf. C. pittsi	"Monoceratina" sp. D	Fissocarinocythere pidgeoni
Loxoconcha clinocosta	Krithe whitecliffsensis	Loxoconcha minardi	Paracypris sp. 1	Limburgina foresterae
Loxoconcha cretacea	"Planileberis" cf. P. costatana	Loxoconcha renfroensis	Paracypris sp. 4	Loxoconcha striata
Loxoconcha erecticosta	Pterygocythere saratogana		Sphaeroleberis pseudoconcentrica	Orthonotacythere hanai
	Veenia adkinsi		Xestoleberis sp. 2	Platycosta lixula
	Veenia arachoides			Xestoleberis opina
	Veenia parallelopora			Xestoleberis seminulata

Table 7 List of three groups of ostracode genera according to their difference in abundances in certain lithofacies.

Genera occur more commonly in		
Clastic-dominated units	**Carbonate-dominated units**	**Both units**
Amphicytherura	Alatacythere	Argilloecia
Antibythocypris	Ascetoleberis	Brachycythere
Anticythereis	Bairdoppilata	Bythocypris
Aversovalva	Bythoceratina	Curfsina
Cushmanidea	Cuneoceratina	Cytheropteron
Cytheromorpha	Cytherelloidea	Escharacytheridea
Eocytheropteron	Eucythere	Fissocarinocythere
Loxoconcha	Eucytherura	Haplocytheridea
Polylophus	Krithe	Limburgina
	Macrocypris	Orthonotacythere
	“Monoceratina”	Platycosta
	Paracypris	Xestoleberis
	Planileberis	
	Pterygocythere	
	Sphaeroleberis	
	Veenia	

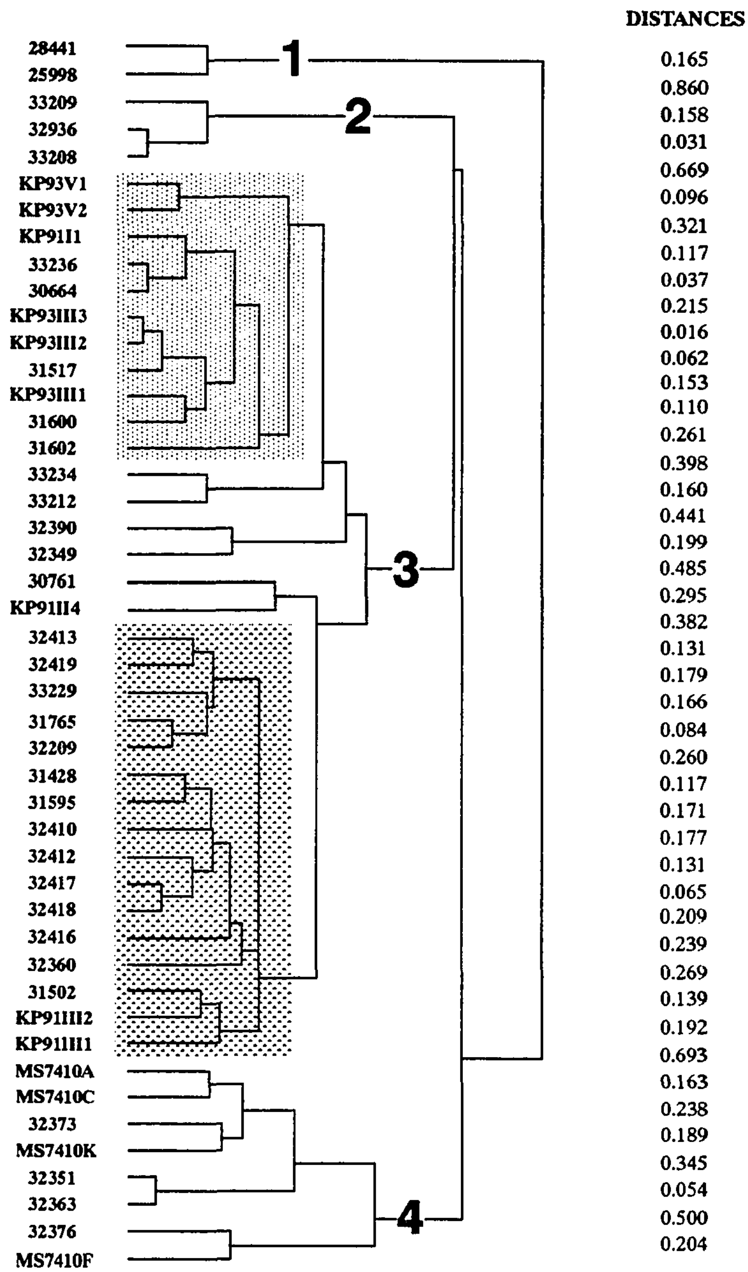


Figure 17 A dendogram based on a cluster analysis of samples. Four major clusters are numbered. Subclusters of cluster #3 are indicated by patterns.

Table 8 Summary of cluster analysis of sample association.

Cluster number	Sample number	Lithologic unit	Geographical area	Comment
1	28441 25988	Providence Sand	Chattahoochee River region	-
2	32936, 33208, 33209	Providence Sand	eastern Alabama	-
3	KP93V1-V2 KPI1, 33236, 30664, KP93III1-3, 31517, 31600, 31602, 33234, 33212, 32390, 32349, 30761, KPII4, 32413, 32419, 33229, 31765, 32209, 31428, 31595, 32410, 32412, 32417, 32418, 32416, 32360, 31502, KP91III1-2	Prairie Bluff Chalk	eastern Alabama, western Alabama and northeast Mississippi	all samples are of Prairie Bluff, except one, 30761 is from Owl Creek Fm.
4	MS7410A, MS7410C, MS7410K, 32373, 32351, 32363, 32376, MS7410F	Owl Creek Formation and Chiwapa Member of Ripley Formation	northeast Mississippi	-

facies 1 C	facies 1 BF	facies 2 C	facies 2 BF	facies 3 C	facies 3 BF	facies 4 C	facies 4 BF	facies 5 C	facies 5 BF	Species
10	•	10	•	5	•	6.8	•	3.6	•	HEVER
10	★									BRHOW
10	●			2.5	•					LMIN
10	⊙	3	•	5	•					FPID
5	○			5	○					ANT6
5	★									ANT8
10	•	10	•	5	•	9.5	•	10	•	BRHO
5	•	10	•	10	•	9.5	•	9.3	•	BOV
		6.7	○	2.5	•	2.6	•	4.3	•	OHAN
		10	⊙			3.2	•	2.9	•	HREN
5	•	10	○	2.5	•					LCRET
		10	○	2.5	•	1.6	•	5	•	XSEMI
		10	●	2.5	•					CYMCFPIT
		3	•	7.5	⊙					LEREC
				5	★					CYMCFARB
				5	○	4.2	•	3.6	•	HGLOB
		3	•	7.5	○	4.2	•	2.9	•	PLIX
10	○	6.7	•	5	•			1.4	•	LCLI
5	⊙			2.5	•					AELONG
10	○			10	○					AMULTI
				7.5	●	1.6	•			APHAS
5	•	6.7	○	5	•	1.6	•			EMAG
				5	⊙			2.9	•	LSTRI
				2.5	⊙					AFOSSL
		3	•	5	•	5.3		7.1	•	XOPI
		10	•	10	•	8.9	•	9.3	•	BFORSL
						1.6	★			ANT10
						2.6	★			VARA
						2.6	⊙	1.4	○	CYTCRAF
		3	•	2.5	•	7.9	○	2.9	•	EPINO
		3	•	7.5	•	9.5	•	7.8	•	BMAG
		3	•	2.5	•	5.8	○			LIMFOR
5	○			5	○	3.7	•			CCAST
5	●					1.6	•			APATAU
						4.2	●			ANT4
10	○			7.5	•	4.7	•			ACRAS
						2.1	★			ANT17
5	•	10	•	10	•	9.5	•	5.7	•	AGOO
5	•	3	•	7.5	•	8.9	•	1.4	•	AMIN
		6.7	•	10	•	8.9	•	3.6	•	ACURTA
						1.6	★			ANT14
5	•	3	•	10	○	6.8	•	2.1	•	AFABA
		10	•	10	•	10	•	9.3	•	CCOMSL
		6.7	○			3.2	•	8.6	○	ASHAZ
						2.6	•	9.3	●	BLED
				2.5	•	8.4	○	7.8	○	FHUNT
						3.2	○	5.7	⊙	CNAV
		6.7	•	5	•	4.7	•	9.3	○	KWHIT
						1.6	•	6.4	●	AAFASER
				7.5	•	8.4	○	7.8	•	HBRUC
		3	•	2.5	•	2.1	•	2.9	•	EMICRO
		6.7	○			4.7	•	6.4	○	BYWIN
10	•	10	•	10	•	10	•	10	•	CYTSPP
						6.3	○	10	⊙	PTSARA
				2.5	•	3.7	•	6.4	○	CYTBISL
								3.6	★	CCORY
								6.4	★	VPARA
						1.6	○	2.1	⊙	VADK
				5	•	5.8	○	4.3	•	PCFPCOS
						1.6	○	1.4	○	CYTAUS
								2.1	⊙	ESOHL

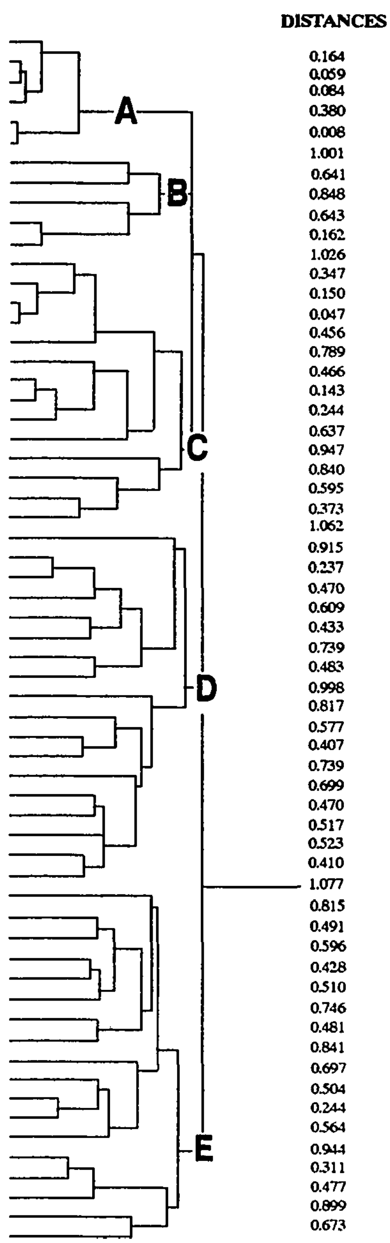


Figure 18 R-mode dendrogram for species of ostracodes occurring in samples from the Upper Cretaceous Prairie Bluff, Providence, Owl Creek and Chiwapa of eastern Alabama to northeastern Mississippi. Full names of species are listed in Table 9. To the left of the dendrogram list the sample constancy (C) and biofacies fidelity (F) value for a species. Table 11 list the C and F values. The C values listed here are those that are greater than 1. (• when BF = 2,3; ○ when BF = 4,5; ⊙ when BF = 6,7; ● when BF =8,9; ★ when BF = 10)

Table 9 Full names of ostracode species that were abbreviated in the cluster analysis.

Abbreviation	Full name	Abbreviation	Full name
AAFASER	Alatacythere aff. A. serrata	CYTAUS	Cytherelloidea austinensis
ACRAS	Antibythocypris crassa	CYTBISL	Cytherelloidea bicosta s.l.
ACURTA	Amphicytherura curta	CYTCRAF	Cytherelloidea crafti
AELONG	Antibythocypris elongata	CYTSPP	Cytherella spp.
AFABA	Antibythocypris fabaformis	EMAG	Escharacytheridea magnamandibulata
AFOSSL	Aversovalva fossatum s.l.	EMICRO	Escharacytheridea micropunctata
AGOO	Antibythocypris gooberi	EPINO	Escharacytheridea pinochii
AMIN	Antibythocypris minuta	ESOHL	Eucythere sohli
AMULTI	Antibythocypris multilira	FHUNT	Fissocarinocythere huntensis
ANT6	Anticythereis sp. 6	FPID	Fissocarinocythere pidgeoni
ANT8	Anticythereis sp. 8	HBRUC	Haplocytheridea bruceclarki
ANT10	Anticythereis sp. 10	HEVER	Haplocytheridea everetti
ANT14	Anticythereis sp. 14	HGLOB	Haplocytheridea globosa
ANT17	Anticythereis sp. 17	HREN	Haplocytheridea renfroensis
ANT4	Anticythereis sp. 4	KWHIT	Krithe whitecliffsensis
APATAU	Antibythocypris pataulensis	LCLI	Loxoconcha clinocosta
APHAS	Antibythocypris phaseolites	LCRET	Loxoconcha cretacea
ASHAZ	Ascetoleberis hazardi	LEREC	Loxoconcha erecticosta
BFORSL	Brachycythere foraminosa s.l.	LIMFOR	Limburgina foresterae
BLED	Brachycythere ledaforma	LMIN	Loxoconcha minardi
BMAG	Bairdoppilata magna	LSTRI	Loxoconcha striata
BOV	Brachycythere ovata	OHAN	Orthonotacythere hannai
BRHO	Brachycythere rhomboidalis	PLIX	Platycosta lixula
BRHOW	B. rhomboidalis (ridge form)	PCFPCOS	"Planileberis" cf. P. costatana
BYWIN	Bythocypris windhami	PTSARA	Pterygocythere saratogana
CCAST	Cytheropteron castorensis	VADK	Veenia adkinsi
CCOMSL	Curfsina communis s.l.	VARA	Veenia arachoides
CCORY	Cytheropteron coryelli	VPARA	Veenia parallelopora
CNAV	Cytheropteron navarroense	XOPI	Xestoleberis opina
CYMCFARB	Cytheromorpha cf. C. arbenzi	XSEMI	Xestoleberis seminulata
CYMCFPIT	Cytheromorpha cf. C. pittsi		

Mississippi. Cluster E represents characteristic species of Prairie Bluff samples of western Alabama and northeast Mississippi. Therefore, the grouping of Cluster #3 was not only principally influenced by cluster E but also by cluster C and D. The grouping by cluster analysis when compares to the distribution pattern reveals a similar relationship between ostracode assemblages and the lithologic units. Figures 19 and 20 are generalized distribution pattern of important ostracode species and genera in the uppermost Maastrichtian deposit.

To determine which species is the most useful for identification of biofacies, the sample constancy and biofacies fidelity of species were calculated (Table 11). Species with high values of constancy and fidelity are the most useful (Hazel, 1970). This technique can be used with both binary (presence and absence) and multistate (counts or relative abundances). Both binary and multistate data were used to calculate, and yielded a similar result. For this study the binary data produced the best result with the least trouble spots. The constancy and fidelity values were tabulated alongside the R-mode dendrogram in Figure 18. The most useful species for identification of biofacies 1 which characterized the Providence Sand samples of the Chattahoochee River area, are Brachycythere rhomboidalis (ridge form), Loxoconcha minardi, Fissocarinocythere pidgeoni and Anticythereis sp. 8. For biofacies 2 which characterized the Providence Sand samples of eastern Alabama can be identified by Orthonotacythere hannai, Haplocytheridea renfroensis and Loxoconcha cretacea. To identify biofacies 3 which characterized the Prairie Bluff of eastern and central Alabama, the following species are the most useful: Loxoconcha erecticosta, Cytheromorpha cf. C. arbenzi, Haplocytheridea globosa, Platycosta lixula, Antibythocypris multilira, Antibythocypris phaseolites, Loxoconcha striata and Aversovalva fossata. The most useful species for identification of biofacies 4 which characterized the samples of Owl Creek Formation and Chiwapa Member of Ripley

Table 10 Summary of the cluster analysis of ostracode species (R-mode).

Cluster number	Species	Comment
A	HEVER, BRHOW, LMIN, FPID, ANT6, ANT8	This group of species characterized samples of the Providence Sand of the Chattahoochee River region.
B	BRHO, BOV, OHAN, HREN, LCRET	This group of species characterized samples of the Providence Sand of eastern Alabama.
C	XSEMI, CYMCFPIT, LEREC, CYMCFARB, HGLOB, PLIX, LCLI, AELONG, AMULTI, APHAS, EMAG, LSTRI, AFOSSL, XOPI	This group of species characterized samples of the Prairie Bluff of eastern and central Alabama that are clayey sand or sandy clay. One Owl Creek sample was characterized by this group as well.
D	BFORSL, ANT10, VARA, CYTCRAF, EPINO, BMAG, LIMFOR, CCAST, APATAU, ANT4, ACRAS, ANT17, AGOO, AMIN, ACURTA, ANT14, AFABA, CCOMSL	This group of species characterized samples of Owl Creek Formation and Chiwapa Member of Ripley Formation of northeast Mississippi. They also characterized samples of Prairie Bluff of western Alabama and northeast Mississippi that are from the basal or lower part.
E	ASHAZ, BLED, FHUNT, CNAV, KWHIT, AAFASER, HBRUC, EMICRO, BYWIN, CYTSPP, PTSARA, CYTBISL, CCORY, VPARA, VADK, PCFPCOS, CYTAUS, ESOHL	This group of species characterized samples of Prairie Bluff of western Alabama and northeast Mississippi. All samples are from the upper part of the Prairie Bluff, but one of central Alabama and one of northeast Mississippi are from the lower part.

Table 11 A list of the sample constancy (C) and biofacies fidelity (BF) of species used in the cluster analysis. The grouping of species and biofacies is the result of R-mode cluster analysis. The sample constancy and biofacies fidelity values were summarized and presented with the R-mode dendrogram in Figure 4.16.

Cluster A	Biofacies 1		Biofacies 2		Biofacies 3		Biofacies 4		Biofacies 5	
Species	C	BF	C	BF	C	BF	C	BF	C	BF
HEVER	10	2.8	10	2.8	5	1.4	6.8	1.9	3.6	1.0
BRHOW	10	10.0	0	0	0	0	0	0	0	0
LMIN	10	8.0	0	0	2.5	2.0	0	0	0	0
FPID	10	5.3	3	1.6	5	2.6	1	0.5	0	0
ANT6	5	5.0	0	0	5	5.0	0	0	0	0
ANT8	5	10.0	0	0	0	0	0	0	0	0

Cluster B	Biofacies 1		Biofacies 2		Biofacies 3		Biofacies 4		Biofacies 5	
Species	C	BF	C	BF	C	BF	C	BF	C	BF
BRHO	10	2.2	10	2.2	5	1.1	9.5	2.1	10	2.2
BOV	5	1.1	10	2.3	10	2.3	9.5	2.2	9.3	2.1
OHAN	0	0	6.7	4.2	2.5	1.6	2.6	1.6	4.3	2.7
HREN	0	0	10	6.2	0	0	3.2	1.99	2.9	1.8
LCRET	5	2.8	10	5.6	2.5	1.4	0.5	0.3	0	0

Cluster C	Biofacies 1		Biofacies 2		Biofacies 3		Biofacies 4		Biofacies 5	
Species	C	BF	C	BF	C	BF	C	BF	C	BF
XSEMI	0	0	10	5.2	2.5	1.3	1.6	0.8	5	2.6
CYMCFPIT	0	0	10	8.0	2.5	2	0	0	0	0
LEREC	0	0	3	2.9	7.5	7.1	0	0	0	0
CYMCFARB	0	0	0	0	5	10.0	0	0	0	0
HGLOB	0	0	0	0	5	3.9	4.2	3.3	3.6	2.8
PLIX	0	0	3	1.7	7.5	4.3	4.2	2.4	2.9	1.6
LCLI	10	4.2	6.7	2.8	5	2.1	0.5	0.2	1.4	0.6
AELONG	5	6.7	0	0	2.5	3.3	0	0	0	0
AMULTI	10	4.8	0	0	10	4.8	1	0.48	0	0
APHAS	0	0	0	0	7.5	8.2	1.6	1.8	0	0
EMAG	5	2.7	6.7	3.7	5	2.7	1.6	0.9	0	0
LSTRI	0	0	0	0	5	6.3	0	0	2.9	3.7
AFOSSL	0	0	0	0	2.5	7.1	1	2.8	0	0
XOPI	0	0	3	1.5	5	2.4	5.3	2.6	7.1	3.5

table con'd.

Cluster D	Biofacies 1		Biofacies 2		Biofacies 3		Biofacies 4		Biofacies 5	
Species	C	BF	C	BF	C	BF	C	BF	C	BF
BFORSL	0	0	10	2.6	10	2.6	8.9	2.3	9.3	2.4
ANT10	0	0	0	0	0	0	1.6	10	0	0
VARA	0	0	0	0	0	0	2.6	10	0	0
CYTCRAF	0	0	0	0	0	0	2.6	6.5	1.4	3.5
EPINO	0	0	3	1.8	2.5	1.5	7.9	4.8	2.9	1.8
BMAG	0	0	3	1.1	7.5	2.7	9.5	3.4	7.8	2.8
LIMFOR	0	0	3	2.5	2.5	2.1	5.8	4.8	0.7	0.6
CCAST	5	3.5	0	0	5	3.5	3.7	2.6	0.7	0.5
APATAU	5	7.6	0	0	0	0	1.6	2.4	0	0
ANT4	0	0	0	0	0	0	4.2	8.6	0.7	1.4
ACRAS	10	4.5	0	0	7.5	3.4	4.7	2.1	0	0
ANT17	0	0	0	0	0	0	2.1	10	0	0
AGOO	5	1.2	10	2.5	10	2.5	9.5	2.4	5.7	1.4
AMIN	5	1.9	3	1.2	7.5	2.9	8.9	3.4	1.4	0.5
ACURTA	0	0	6.7	2.3	10	3.4	8.9	3.0	3.6	1.2
ANT14	0	0	0	0	0	0	1.6	10	0	0
AFABA	5	1.9	3	1.1	10	3.7	6.8	2.5	2.1	0.8
CCOMSL	0	0	10	2.5	10	2.5	10	2.5	9.3	2.4

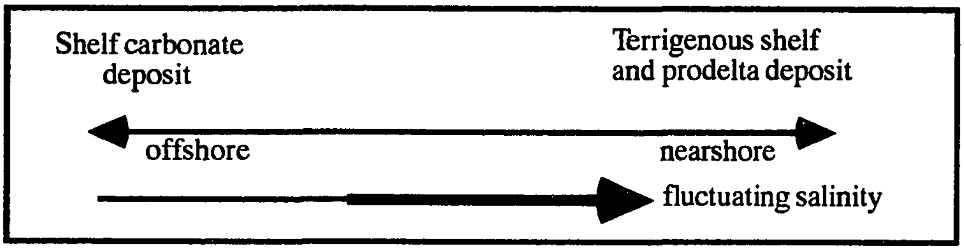
Cluster E	Biofacies 1		Biofacies 2		Biofacies 3		Biofacies 4		Biofacies 5	
Species	C	BF	C	BF	C	BF	C	BF	C	BF
ASHAZ	0	0	6.7	3.6	0	0	3.2	1.7	8.6	4.6
BLED	0	0	0	0	0	0	2.6	2.2	9.3	7.8
FHUNT	0	0	0	0	2.5	1.3	8.4	4.5	7.8	4.2
CNAV	0	0	0	0	0	0	3.2	3.6	5.7	6.4
KWHIT	0	0	6.7	2.6	5	1.9	4.7	1.8	9.3	3.6
AAFASER	0	0	0	0	0	0	1.6	2.0	6.4	8.0
HBRUC	0	0	0	0	7.5	3.2	8.4	3.5	7.8	3.3
EMICRO	0	0	3.0	2.9	2.5	2.4	2.1	2.0	2.9	2.8
BYWIN	0	0	6.7	3.8	0	0	4.7	2.6	6.4	3.6
CYTSPP	10	2.0	10	2.0	10	2.0	10	2.0	10	2.0
PTSARA	0	0	0	0	0	0	6.3	3.9	10	6.1
CYTBISL	0	0	0	0	2.5	1.9	3.7	2.9	6.4	5.1
CCORY	0	0	0	0	0	0	0	0	3.6	10
VPARA	0	0	0	0	0	0	0	0	6.4	10
VADK	0	0	0	0	0	0	1.6	4.3	2.1	5.7
PCFPCOS	0	0	0	0	5	3.3	5.8	3.8	4.3	2.8
CYTAUS	0	0	0	0	0	0	1.6	5.3	1.4	4.7
ESOHL	0	0	0	0	0	0	1.0	3.2	2.1	6.8

Shelf carbonate deposit | Terrigenous shelf and prodelta deposit
offshore ←——→ nearshore
——→ fluctuating salinity

Alatacythere aff. A. serrata
Ascetoleberis hazardi
Bairdoppilata magna
Brachycythere ledaforma
Bythoceratina aff. B. umbonata
Cuneoceratina aff. C. prothroensis
Cuneoceratina prothroensis
Cytherella spp.
Cytherelloidea bicosta s.l.
Cytherelloidea crafti
Cytheropteron coryelli
Cytheropteron navarroense
Eucythere sohli
Haplocytheridea bruceclarki
Krithe whitecliffsensis
"Monoceratina" aff. "M." nitida
"Planileberis" cf. "P." costatana
Pterygocythere saratogana
Sphaeroleberis pseudoconcentrica
Veenia adkinsi
Veenia arachoides
Veenia parallelopora

Amphicytherura curta
Antibythocypris crassa
Antibythocypris elongata
Antibythocypris fabaformis
Antibythocypris gooberi
Antibythocypris minuta
Antibythocypris multilira
Antibythocypris pataulensis
Antibythocypris phaseolites
Anticythereis sp. 4
Anticythereis sp. 6
Anticythereis sp. 8
Anticythereis sp. 14
Anticythereis sp. 17
Aversovalva fossata s.l.
Brachycythere rhomboidalis
Cytheromorpha cf. C. arbenzi
Cytheromorpha cf. C. pittsi
Escharacytheridea magnamandibulata
Haplocytheridea everetti
Haplocytheridea renfroensis
Loxoconcha clinocosta
Loxoconcha cretacea
Loxoconcha erecticosta
Loxoconcha minardi
Loxoconcha striata
Xestoleberis opina
Xestoleberis seminulata

Figure 19 Distribution of ostracode species in the uppermost Maastrichtian deposits of the eastern Gulf Coastal Plain.



Alatacythere
Ascetoleberis
Bairdoppilata*
Bythoceratina*
Cuneoceratina
Cytherella*
Cytherelloidea*
Cytheropteron*
Eucythere*
Eucytherura*
Krithe*
Macrocypris*
"Monoceratina" *
Paracypris*
"Planileberis"
Pterygocythere
Veenia

Amphicytherura
Antibythocypris
Anticythereis
Aversovalva
Cytheromorpha*
Haplocytheridea
Loxoconcha*
Xestoleberis*

Figure 20 Distribution of ostracode genera in the uppermost Maastrichtian deposits of the eastern Gulf Coastal Plain. (* indicates genus that has a present-day representative)

Formation of northeast Mississippi and samples of basal or lower part of the Prairie Bluff of western Alabama and northeast Mississippi, are Anticythereis sp. 10, Veenia arachoides, Cytherelloidea crafti, Escharacytheridea pinochii, Bairdoppilata magna, Limburgina foresterae, Anticythereis sp. 4, Anticythereis sp. 17, Antibythocypris minuta, and Anticythereis sp. 14. To identify biofacies 5 which characterized samples from the upper part of the Prairie Bluff of western Alabama and northeast Mississippi, the following species are the most useful: Ascetoleberis hazardi, Brachycythere ledaforma, Cytheropteron navarroense, Krithe whitecliffsensis, Alatacythere aff. A. serrata, Escharacytheridea micropunctata, Cytherella spp., Pterygocythere saratogana, Cytherelloidea bicosta s.l., Cytheropteron coryelli, Veenia parallelopora, Veenia adkinsi, and Eucythere sohli.

The distribution of five diagnostic species, Platycosta lixula, Brachycythere foraminosa s.l., Veenia parallelopora, Veenia adkinsi and Fissocarinocythere pidgeoni, used for recognizing the Maastrichtian ostracode zones were plotted in Figures 21 and 22. Two ostracode interval zones, Platycosta lixula and Veenia parallelopora, were proposed for the lower and upper Maastrichtian respectively (Hazel and Brouwers, 1982, Pitakpaivan and Hazel, 1994). The distribution of P. lixula is widespread both geographically and stratigraphically. It occurred throughout the study area except the Providence Sand of the Chattahoochee River region. The distribution of V. parallelopora and V. adkinsi, however is less widespread. These two species of Veenia occurred only in the Prairie Bluff Formation of central Alabama, western Alabama and northeast Mississippi. In central and western Alabama, V. parallelopora is found only in the uppermost part of the Prairie Bluff. However, in northeast Mississippi it is found from the basal part to the uppermost part of the Prairie Bluff. The distribution of B. foraminosa s.l. is similar to that of P. lixula. In contrast to the other four species, F. pidgeoni is found in significant number in Providence Sand of the Chattahoochee River region, and very rarely found (one to five specimens) in some Prairie Bluff samples of central Alabama and northeast Mississippi.

Therefore the lower part of the Providence Sand of the Chattahoochee River region is assigned to lower Maastrichtian P. lixula Interval Zone which was defined as the interval between the evolutionary first appearance datum (FAD) of P. lixula and the FAD of V. parallelopora. The Alexander's Landing Beds samples on the other hand contains only seven species including Brachycythere ovata, Cytherella spp. as major component and Antibythocypris crassa, Antibythocypris multilira and Curfsina communis as minor component. Therefore, a precise placement of this bed is not possible. The Providence Sand of eastern Alabama, the Prairie Bluff Formation and the Owl Creek Formation are assigned to upper Maastrichtian V. parallelopora Interval Zone which was defined as an interval between the FAD of V. parallelopora and the FAD of Brachycythere plena. Although V. parallelopora was not found throughout, the presence of B. foraminosa s.l. indicates the chronozone. The Chiwapa Member of the Ripley Formation is possibly assigned to the lowermost of the V. parallelopora zone. The Chiwapa contained not only P. lixula and B. foraminosa s.l. but also Brachycythere porosa which is common in older units.

DISCUSSIONS AND CONCLUSIONS

As shown in this study, the distribution of ostracodes of the uppermost Maastrichtian of the eastern Gulf Coastal Plain agrees with a major lithologic change that reflects a difference in paleoenvironmental conditions. In general, congeneric species, with the exception of species of Haplocytheridea, exhibit a similar pattern of distribution . Haplocytheridea everetti and Haplocytheridea renfroensis are common in clastic units, whereas Haplocytheridea bruceclarki is common in carbonate units. Among 24 genera listed in Figure 20, 12 have present-day representatives; their known distributions are given in Table 12.

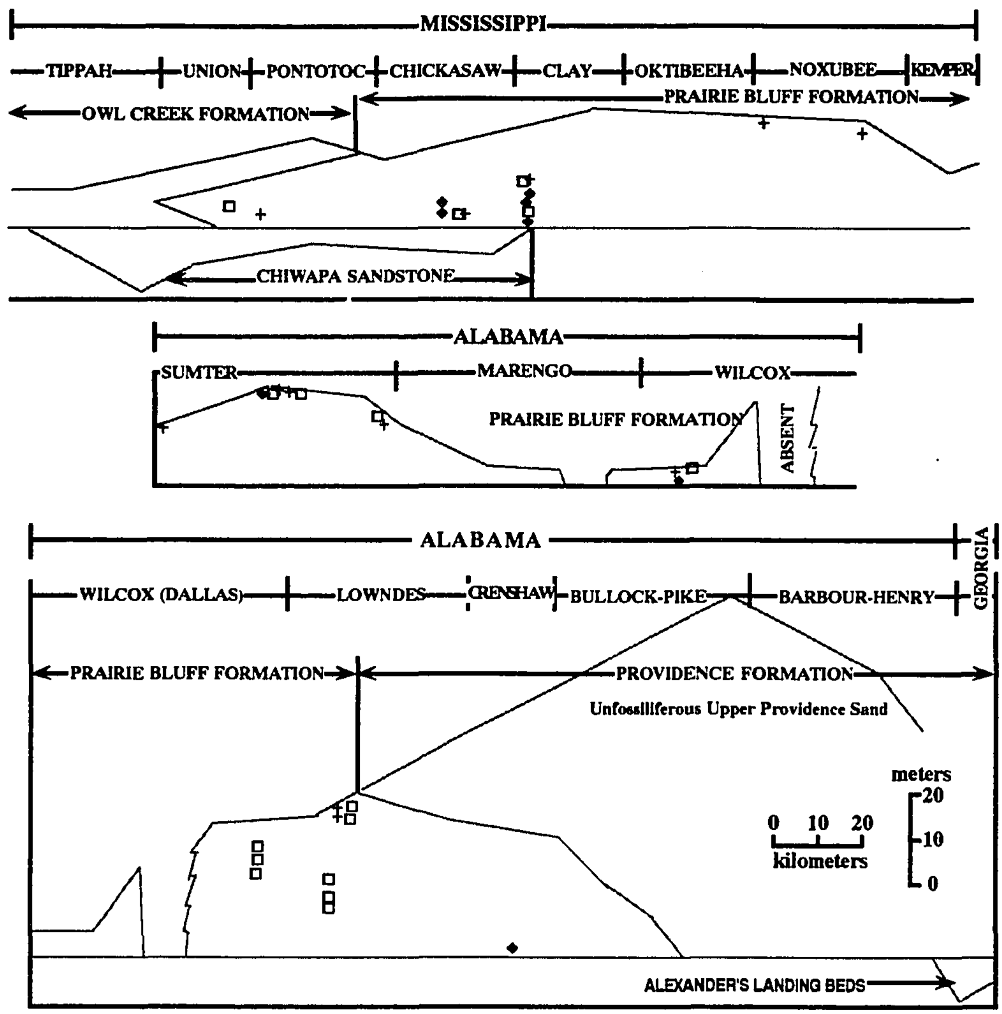


Figure 21 Stratigraphic and geographic distribution of Veenia pararellopora (+), Veenia adkinsi (□), and Veenia arachoides (◆). Lithostratigraphic relationship modified from Sohl & Koch (1986) and Sohl (1960). Gray solid lines are lithologic boundaries.

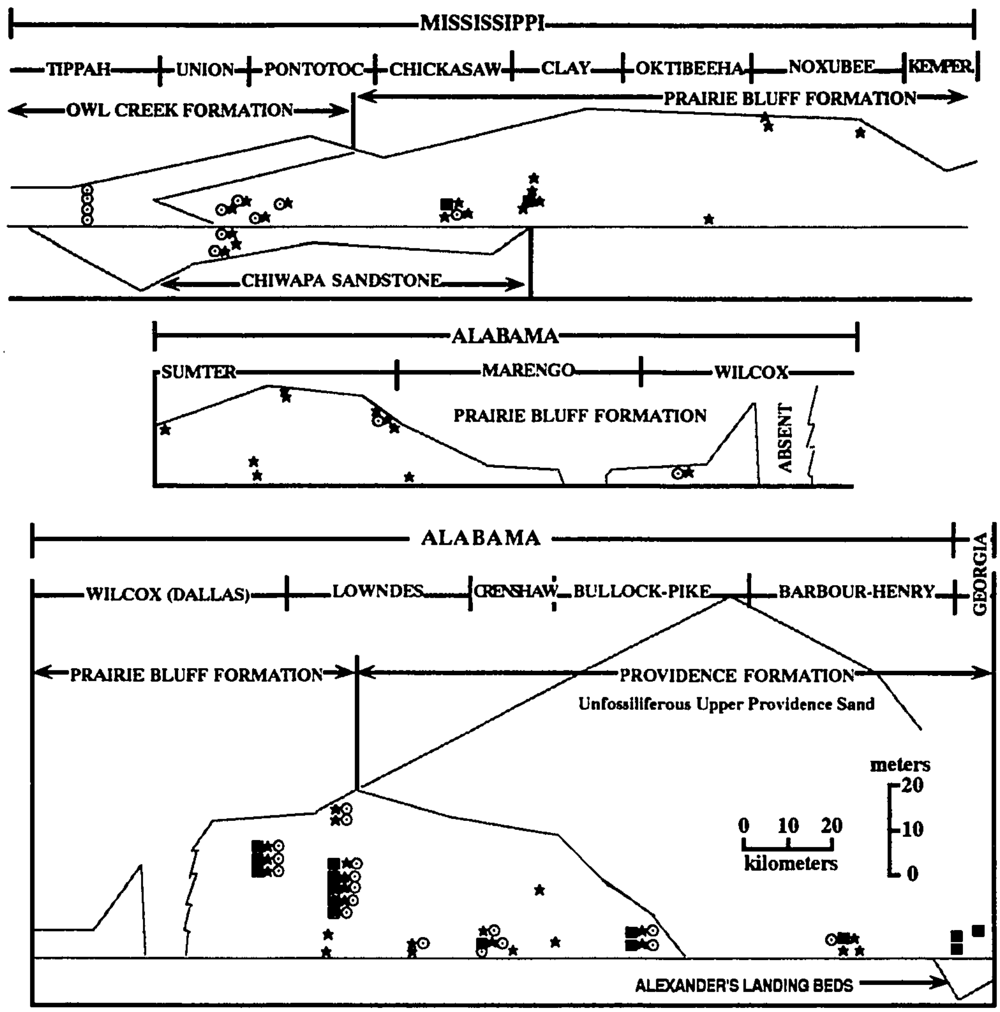


Figure 22 Stratigraphic and geographic distribution of Brachycythere foraminosa s.l. (★), Platycosta lixula (⊙) and Fissocarinocythere pidgeoni (■). Lithostratigraphic relationship modified from Sohl & Koch (1986) and Sohl (1960). Gray solid lines are lithologic boundaries.

Table 12 List of known ecological distribution of ostracode genera of the uppermost Maastrichtian deposits. (* indicates genus that has a present-day representative)

Genus	Known ecological distribution (from van Morkhoven, 1962)	Known bathymetric environment of recent representatives in the Northwestern Gulf of Mexico (from van Morkhoven, 1972)
Amphicytherura	marine	–
Bairdia*	marine all depth	–
Brachycythere	marine	–
Bythocypris*	marine-bathyal	bathyal to abyssal (180 to 2400 meters)
Cushmanidea	epineritic	–
Cytherella*	marine all depth	middle neritic to upper slope (bathyal) (21 to 360 meters)
Cytherelloidea*	warmer epineritic	middle neritic (70 to 300 meters)
Cytheromorpha*	mesohaline to littoral	brackish water to middle neritic (90 meters)
Cytheropteron*	marine all depth	middle neritic to abyssal (21 to 3600 meters)
Eucythere*	marine all depth	middle neritic to upper slope (bathyal) (21 to 240 meters)
Eucytherura*	marine	–
Krithe*	infraneritic and bathyal	middle neritic to abyssal (60 to 3600 meters)
Loxoconcha*	mesohaline to littoral	beach-tidal zone to outer neritic (120 meters)
Macrocypris*	infraneritic, bathyal	–
"Monoceratina" *	marine	–
Orthonotacythere	marine	–
Paracypris*	marine	middle to outer neritic (45 to 180 meters)
"Planileberis"	marine	
Pterygocythere*	marine	middle neritic to upper slope (bathyal) (21 to 240 meters)
Veenia	marine	–
Xestoleberis*	littoral to epineritic	middle neritic to abyssal (30 to 3600 meters)

The Maastrichtian assemblage of the Providence Sand and Owl Creek Formation is typified by representatives of Amphicytherura, Antibythocypris, Anticythereis, Aversovalva, Cytheromorpha, Haplocytheridea, Loxoconcha and Xestoleberis. As shown in Table 4.12, the present-day representatives of these genera occupy a similar habitat. Today, Loxoconcha and Cytheromorpha are more common in the shallow waters of the inner shelf than the middle or outer shelf (Whatley, 1988). Xestoleberis has been observed to prefer substrates with plants such as and can tolerate a wide range of salinities (Whatley, 1988; Bate, 1971). Antibythocypris and Haplocytheridea have no living representatives. However, they belong to the Cytherideidae whose present-day representatives are generally found in near-shore habitats and some forms are known to be tolerant of variable salinities. Considering the faunal characteristic and low to moderate diversity of these units, they are interpreted to be have been deposited on the inner shelf with relative nearness to the coast. The interpretation made here is that the ostracode assemblages suggests terrigenous shelf and prodelta sites of deposition. Such an interpretation agrees with previous studies based on other types of data (Donovan, 1986; Sohl and Smith, 1980; Sohl and Koch, 1986).

On the other hand, the assemblage of the Prairie Bluff Formation is typified by representatives of Bairdoppilata, Cytherella, Cytherelloidea, Cytheropteron, Eucythere, Eucytherura, Krithe, Macrocypris, Monoceratina and Paracypris. The Bairdia group is found in present-day warm normal marine (euhaline) environment, and is commonly in association with carbonate environments(Whatley, 1988; Kornicker, 1961). It has been observed to be restricted to water salinities greater than 31 ‰ (Kornicker, 1961; Maddocks, 1969). The Cytherella group is also commonly found in normal marine environments and has wide depth range (van Morkhoven, 1972; Kornicker, 1963). Modern deeper water, offshore deposits are characterized by the increasing significance of Krithe, Cytheropteron, Bythocyrpis, and Eucythere. The Prairie Bluff is interpreted to represent middle to outer shelf deposition. This supports previous interpretations (Sohl and Koch, 1986). In conclusion, this study has shown that Upper Cretaceous ostracodes and their present-day representatives have occupied similar habitats. Therefore, paleoenvironmental interpretations of Upper Cretaceous Gulf Coastal Plain deposits can be done by analogy using ostracode distribution patterns.

Considering biostratigraphic position of these uppermost Maastrichtian units, Platycosta lixula and Brachycythere foraminosa s.l. have shown to be very useful and reliable species. They do not confined to any particular lithofacies, and are widely distributed not only throughout this study area but also in correlative Maastrichtian units of Arkansas and Texas.In the eastern Gulf Coast region, Veenia parallelopora and Veenia adkinsi were found to be confined to the Prairie Bluff Formation. However, Veenia. parallelopora actually is not confined geographically. It is known to occur in the Maastrichtian units of Texas and Arkansas. The ostracode biostratigraphy suggests that the lower part of the Providence Sand of the Chattahoochee River area is slightly older than that of eastern Alabama where it gradually merges into the Prairie Bluff Formation. The Providence Sand of eastern Alabama and the coeval Prairie Bluff Formation and Owl Creek Formation are within the upper Maastrichtian Veenia parallelopora Interval Zone.

REFERENCES TO CHAPTER IV

Alexander, C. I., 1929, Ostracoda of the Cretaceous of North Texas: University of Texas Bulletin, 2907, 1-137.

Alexander, C. I., 1933, Shell structure of the Genus Cytheropteron, and species from the Cretaceous of Texas: Journal of Paleontology, 7, 181–214.

Alexander, C. I., 1934, Ostracoda of the Midway (Eocene) of Texas: Journal of Paleontology, 8, 206-237.

Alexander, C. I., 1936, Ostracoda of the Genera Eucythere, Cytherura, and Loxoconcha from the Cretaceous of Texas: Journal of Paleontology, 10, 689–694.

Bate, R. and Robinson, E., Ed., 1978, A stratigraphical index of British Ostracoda: Liverpool, Seel House Press.

Bate, R. H., 1971, The distribution of Recent Ostracoda in the Abu Dhabi Lagoon, Persian Gulf: *in* Oertli, H. J., eds., Proceedings of the Colloquium on the Paleoecology of Ostracodes: SNPA, Elf-Aquitaine, Pau, 239-256.

Barron, E. J., 1987, Cretaceous plate tectonic reconstructions: Palaeogeography, Palaeoclimatology, Palaeoecology, 59, 3-29.

Berry, E. W., 1925, Upper Cretaceous Ostracoda from Maryland: American Journal of Science, 9, 481–487.

Brouwers, E. M. and Hazel, J. E., 1978, Ostracoda and correlation of the Severn Formation (Navarroan; Maestrichtian) of Maryland: Society of Economic Paleontologists and Mineralogists Paleontological Monograph, (1), 52 p.

Butler, E. A. and Jones, D. E., 1957, Cretaceous Ostracoda of Prothro and Rayburns Salt Domes, Bienville Parish, Louisiana: Louisiana Geological Survey Geological Bulletin, 32, 1–62.

Buzas, M. A., Koch, C. F., Culver, S. J. and Sohl, N. F., 1982, On the distribution of species occurrence: Paleobiology, 8(2), 143-150.

Chimene, J. B., II and Maddocks, R. F., 1984, Ostracode biostratigraphy and paleoecology of the Upper Taylor Group (Campanian, Upper Cretaceous) in central Texas: Gulf Coast Association of Geological Societies Transactions, 34, 311-320.

Copeland, C. W., 1968, Facies changes in the Selma Group in central and eastern Alabama: *in* Scott, J. C., Chm., eds., Facies changes in the Selma Group in central and eastern Alabama: Alabama Geological Society Guidebook 6th Field Trip: 2-26.

Crane, M. J., 1965, Upper Cretaceous ostracodes of the Gulf Coast area: Micropaleontology, 11(2), 191–254.

Donovan, A. D., 1986, Sedimentology of the Providence Formation: *in* Reinhardt, J., eds., Stratigraphy and sedimentology of continental, nearshore, and marine Cretaceous sediments of the eastern Gulf Coastal Plain: Society of Economic Paleontologists and Mineralogists Annual Meeting Field Trip #3: 29-44.

Gibson, T. G. and Buzas, M. A., 1973, Species diversity: patterns in modern and Miocene foraminifera of the eastern margin of North America: GSA Bulletin, 84, 217-238.

Habib, D., Moshkovitz, S. and Kramer, C., 1992, Dinoflagellate and calcareous nannofossil response to sea-level change in Cretaceous-Tertiary boundary sections: Geology, 20(2), 165-168.

Haq, B. U., 1984, Paleoceanography: A synoptic overview of 200 million years of ocean history: *in* Haq, B. U. and Milliman, J. D., eds., Marine geology and oceanography of Arabian sea and coastal Pakistan: Van Nostrand Reinhold Company, New York, 201-231.

Hazel, J. E., 1970, Binary coefficients and clustering in biostratigraphy: Geological Society of America Bulletin, 81, 3237-3252.

Hazel, J. E. and Brouwers, E. M., 1982, Biostratigraphic and chronostratigraphic distribution of ostracodes in the Coniacian–Maastrichtian (Austinian–Navarroan) in the Atlantic and Gulf Coastal Province: *in* Maddocks, R. F., eds., Texas Ostracoda: Department of Geosciences, University of Houston, Houston, 166–198.

Holden, J. C., 1964, Upper Cretaceous ostracods from California: Palaeontology, 7, 393–429.

Howe, H. V. and Laurencich, L., 1958, Introduction to the study of Cretaceous Ostracoda: Louisiana State University Press, Baton Rouge, 536 p.

Israelsky, M. C., 1929, Upper Cretaceous Ostracoda of Arkansas: Arkansas Geological Survey Bulletin, 2, 3–29.

Jennings, P. H., 1936, A microfauna from the Monmouth and basal Rancocas Groups of New Jersey: Bulletins of American Paleontology, 23, 161–235.

Kornicker, L. S., 1961, Ecology and taxonomy of Recent Bairdiinae (Ostracode): Micropaleontology, 7(1), 55-70.

Kornicker, L. S., 1963, Ecology and classification of Bahamian Cytherellidea (Ostracoda): Micropaleontology, 9(1), 61-70.

LaMoreaux, P. E. and Toulmin, L. D., 1959, Geology and groundwater resources of Wilcox County, Alabama: Alabama Geological Survey County Report, 4, 280p.

MacArthur, R. H. and MacArthur, J. W., 1961, On bird species diversity: Ecology, 42, 594-598.

Maddocks, R. F., 1969, Revision of Recent Bairdiidae (Ostracoda): United States National Museum Bulletin, 295, 126 p.

Maddocks, R. F., 1985, Ostracoda of Cretaceous-Tertiary contact sections in Central Texas: Gulf Coast Association of Geological Societies Transactions, 35, 445-456.

Mancini, E. A., Tew, B. H. and Smith, C. C., 1989, Cretaceous-Tertiary contact, Mississippi and Alabama: Journal of Foraminiferal Research, 19(2), 93-104.

Mancini, E. A., Tew, B. H. and Smith, C. C., 1989, Cretaceous-Tertiary contact, Mississippi and Alabama: Journal of Foraminiferal Research, 19, 93-104.

Morkhoven, F. P. C. M. van, 1972, Bathymetry of recent marine Ostracoda in the northwest Gulf of Mexico: Gulf Coast Association of Geological Societies Transactions, 22, 241-252.

Olsson, R. K. and Lui, C., 1992, A Biostratigraphically continuous Cretaceous/Paleogene section at Millers Ferry, Alabama:Support for a Bolide Impact: Geological Society of America, Annual Meeting, Cincinnati, Ohio, A29

Olsson, R. K. and Lui, C., 1993, Controversies on the Placement of Cretaceous-Paleogene Boundary and the K/P Mass Extinction of Planktonic Foraminifera: Palaios, 8, 127-139.

Pielou, E. C., 1966, The measurement of diversity in different types of biological collections: Journal of Theoretical Biology, 13, 131-144.

Pitakpaivan, K. and Hazel, J. E., 1994, Ostracodes and Chronostratigraphic position of the Upper Cretaceous Arkadelphia Formation of Arkansas: Journal of Paleontology, 68(1), 111-122.

Puckett, T. M., 1994, Ostracode Biostratigraphy of the Demopolis Chalk (Campanian and Maastrichtian) in eastern Mississippi: Mississippi Geology, 15(1), 3-7.

Russell, E. E., Keady, D. M., Mancini, E. E. and Smith, C. C., Ed., 1983, Upper Cretaceous Lithostratigraphy and Biostratigraphy in Northeast Mississippi, Southwest Alabama, and Northwest Alabama, Shelf Chalks and Clastics: Field Trip Guidebook for 1983 Spring Field Trip of Gulf Coast Section: Society of Economic Paleontologists and Mineralogists.

Smith, C. C. and Mancini, E. E., 1983, Calcareous Nannofossil and Planktonic Foraminiferal Biostratigraphy: *in* Russell, E. E., Keady, D. M., Mancini, E. E. and Smith, C. C., eds., Upper Cretaceous Lithostratigraphy and Biostratigraphy in Northeast Mississippi, Southwest Alabama, and Northwest Alabama, Shelf Chalks and Clastics: Field Trip Guidebook for 1983 Spring Field Trip of Gulf Coast Section, Society of Economic Paleontologists and Mineralogists: 16-28.

Smith, J. K., 1978, Ostracoda of the Prairie Bluff Chalk, Upper Cretaceous, (Maestrichtian) and the Pine Barren Member of the Clayton Formation, Lower Paleocene, (Danian) from exposures along Alabama state highway 263 in Lowndes County, Alabama: Gulf Coast Association of Geological Societies Transactions, 28, 539–579.

Sohl, N. F., 1960, Archaeogastropods, mesogastropods, and stratigraphy of the Ripley, Owl Creek and Prairie Bluff Formations: U.S. Geological Survey Professional Paper 331A, 151 p.

Sohl, N. F., 1977, Utility of gastropods in biostratigraphy: *in* Kauffman, E. G. and Hazel, J. E., eds., Concepts and methods of biostratigraphy: Downden, Hutchinson and Ross, Inc, Stroudsburg, Pennsylvania., 519–540.

Sohl, N. F. and Koch, C., 1986, Molluscan biostratigraphy and biofacies of the Huastator bilira assemblage zone (Maastrichtian) of the East Gulf Coastal Plain: *in* Reinhardt, J., eds., Stratigraphy and sedimentology of continental, nearshore, and marine Cretaceous sediments of the Eastern Gulf Coastal Plain, Field Trip No. 3: Society of Economic Paleontologists and Mineralogists Annual Meeting, 45-56.

Sohl, N. F., Martínez R., E., Salmerón-Ureña, P. and Soto-Jaramillo, F., 1991, Upper Cretaceous: *in* Salvador, A., eds., The Gulf of Mexico Basin: The Geological Society of America Inc., Boulder, CO, 205-242.

Sohl, N. F. and Owens, J. P., 1990, Cretaceous stratigraphy of the Carolina Coastal Plain: *in* Horton, J. W., Jr. and Zullo, V. A., eds., The geology of the Carolinas: Carolina Geological Society 50th Anniversary Volume: 191-220.

Stephenson, L. W. and Monroe, W. H., 1940, The Upper Cretaceous deposits: Mississippi State Geological Survey Bulletin 40, 296 p.

Whatley, R. C., 1988, Ostracoda and Palaeogeography: *in* De Deckker, P., Colin, J. and Peypouquet, J., eds., Ostracoda in the Earth Sciences: Elsevier, New York, 103-123.

Wilkinson, L., M., H., S., M., Howe, P. and Vang, E., 1992, SYSTAT for the Macintosh: Evanston, SYSTAT, Inc.

CHAPTER V

OSTRACODA OF CRETACEOUS–TERTIARY CONTACT SECTIONS IN ALABAMA AND MISSISSIPPI

INTRODUCTION

Since the early decades of the nineteenth century, earth scientists have recognized that there were major changes in the earth's biota at the end of the Cretaceous and the beginning of the Tertiary (for example, extinction of the dinosaurs, large marine reptiles, ammonites, etc., and diversification of the mammals, birds, etc.). Indeed, these observed changes are in large part the basis for the distinction between these systems. In the last fifteen years, there has been great interest in the Cretaceous-Tertiary (K-T) boundary interval, mainly as a result of an extraterrestrial impact hypothesis proposed by Alvarez and others (1980). Such an impact could explain excess amounts of the rare platinum family element Iridium at the boundary, and also account for the disappearance of many taxonomic groups (mass extinction) from the rock record and the interdiction of other. This has transformed research on the boundary interval from one of primarily paleontological focus to a multidisciplinary, and provocative, world-wide effort. Recently, the Chicxulub structure on what is now the Yucatuan Peninsula of Mexico has been championed as the site of the K-T impact (Hildebrand and others, 1991). This proposal together with the finding of odd objects in the boundary interval and interpreted to represent impact ejecta fallout and certain deposits said to be the result of impact, generated waves (Hildebrand and others, 1991; Smit and others, 1992); and references in these works), has kindled the controversial fires. This has led to strong opinions, and created pages of discussion.

This paper is not focused on trying to bring resolution to the actual causes of the K-T boundary biotic events -- this no doubt will be debated for some time to come --, but attempts to document in detail the distributional pattern of the ostracodes across the K-T boundary interval in the highly fossiliferous deposits of the eastern Gulf Coastal Plain of Alabama and Mississippi. The ostracodes are Crustacea and the particular taxa under study are forms that are microscopic, marine, benthic, and adapted to sublittoral habitats. They are easily preserved because of their dense calcite carapaces. Because of their size and preservational advantage, they can be sampled in more stratigraphic detail that other metazoans that have been studied in connection with K-T boundary research. Further, they offer a different biological perspective than the calcareous protists, such as the planktic foraminifers and calcareous nannoplankton, that have been the subject of K-T research. The ostracodes have not be studied previously in any detail in connection with the K-T boundary efforts in North America or elsewhere.

The localities treated in this study are the well-known Braggs section in Lowndes County, Alabama, the Shell Creek section in Wilcox County, Alabama, and the Lynn Creek section in Noxubee County, Mississippi. The K-T boundary at these three localities, which represent continental shelf deposits, as well as localities elsewhere in the Gulf Coastal Plain, have generally been considered discontinuous as a result of sea-level fall, and have been presumed to have lesser stratigraphic value than deep sea sections. As a consequence, only a tiny portion of the large body of literature on the K-T boundary is on these Alabama and Mississippi sections; for that matter, most sections elsewhere in the world that represent sublittoral sites of deposition have not been studied in detail with respect to benthic microfossils.

It is a goal of this paper to demonstrate how detailed analyses of the ostracode assemblages can contribute to a better understanding of the stratigraphy and events at the K-T boudary. The Braggs section has been the subject of several studies in the last two decades. These include both paleontological and stratigraphic, including sequence stratigraphic and magnetostratigraphic efforts (Worsley, 1974; Smith, 1978; Copeland and Mancini, 1986; Jones and others, 1987; Donovan and others, 1988; Mancini and others, 1989; Habib and others, 1992; Moshkovitz and Habib, 1993; Habib, 1994). Therefore, this section is very important in that the ostracode distributions can be directly compared to the data and interpretations in these works. It should be pointed out that the subject of the Smith (1978) paper was the distribution of the ostracodes at Braggs. However, it is now in need of virtually complete taxonomic and biostratigraphic revision.

In contrast to Braggs, the stratigraphy of the K-T boundary at Shell Creek and Lynn Creek were documented in any detail only by Mancini and others (1989) and needs further study. By throughly examining ostracode data from these sections, the authors have been able to 1) identify the ostracode interval zones, 2) assess the stratigraphic relationships of the lithostratigraphic units, 3) determine the extinction pattern of the ostracodes with implications as to the nature of the K-T boundary events, and 4) evaluate the completeness of the K-T boundary interval at these sections.

THE CRETACEOUS-TERTIARY BOUNDARY SECTIONS

Figure 23 is a locality map for the Alabama and Mississippi sections studied in this paper. Figures 24 to 26 illustrate the measured sections. The two lithologic units of most interest are the uppermost Cretaceous unit, the Prairie Bluff Formation, and the lower part of the lowermost Tertiary unit, the Clayton Formation. At about 7.4 kilometers southeast of the intersection of Alabama Highway 21 and 263 at the small town of Braggs, excellent outcrops of the K-T boundary are exposed in roadcuts along Alabama Highway 263. As mentioned above, this section has been studied extensively in comparison to other eastern Gulf Coastal Plain sections. The section was measured and described by Smith (1978). Copeland and Mancini (1986) also present a measured section and describe the lithology.

The interval studied is from bed number 2 of Copeland and Mancini (1986) of the Prairie Bluff Formation to the highest bed of the Pine Barren Member of Clayton Formation as exposed at Braggs. The exposed Prairie Bluff Formation at Braggs is late Maastrichtian in age (Pitakpaivan and Hazel, 1994; Habib and others, 1992) and consists of dark grey, silty to sandy, glauconitic, fossiliferous calcareous clay that

Figure 23 Location map of the Cretaceous-Tertiary sections at Braggs, Shell Creek and Lynn Creek.

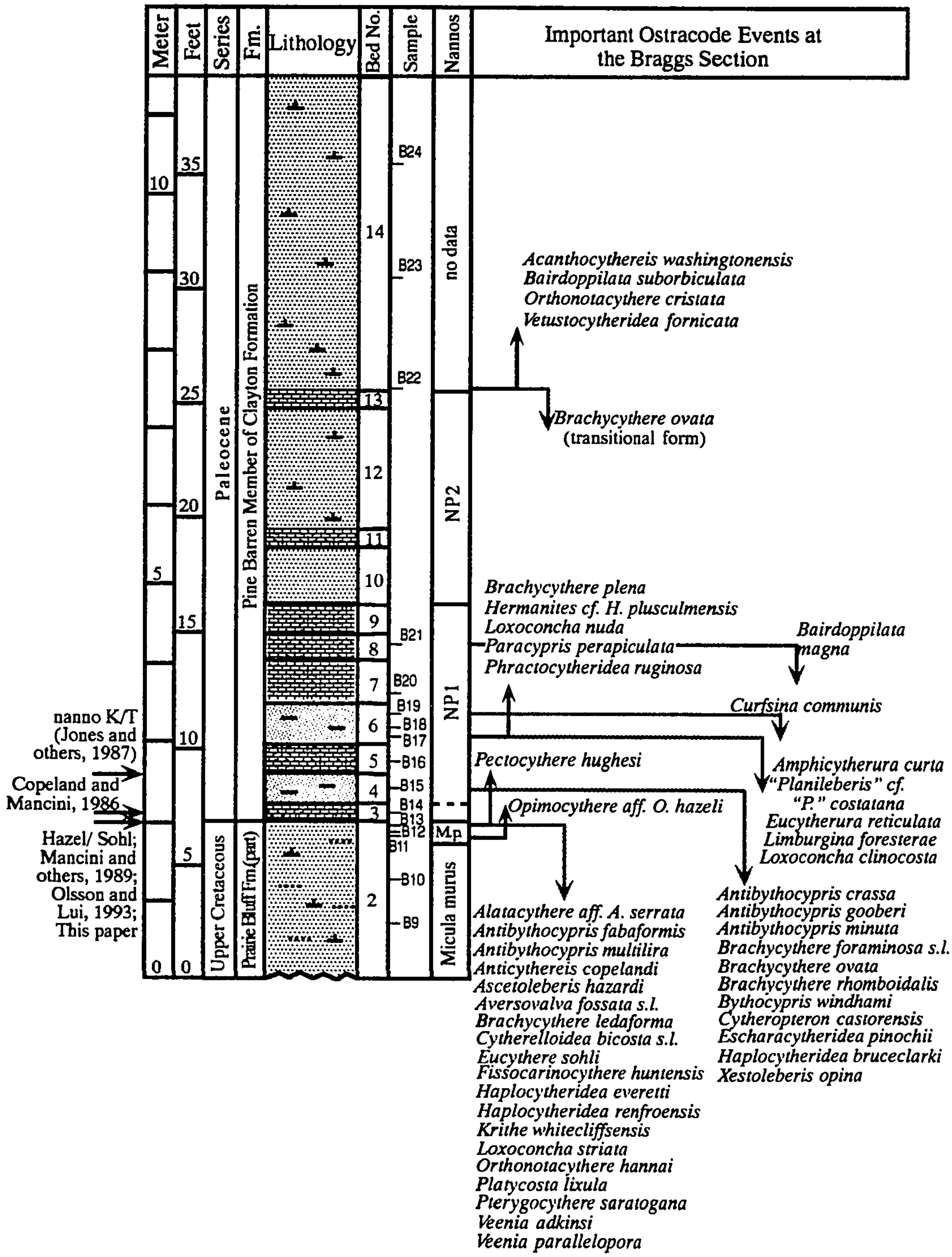


Figure 24 The Cretaceous-Tertiary section at Braggs (modified after Copeland and Mancini,1986). The bed numbers were assigned by Copeland and Mancini (1986). M. p. = Micula prinsii.

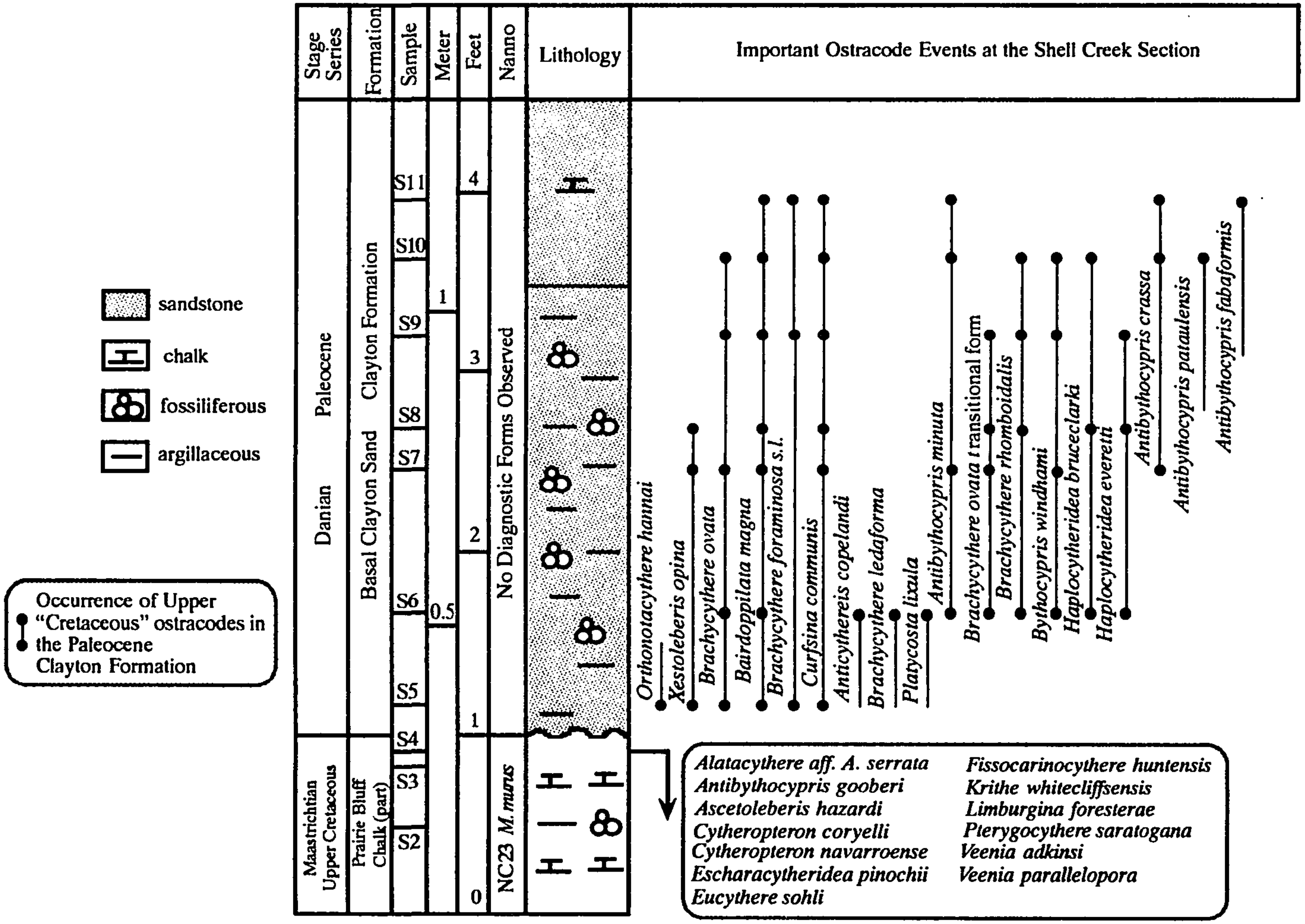


Figure 25 The Cretaceous-Tertiary section at Shell Creek.

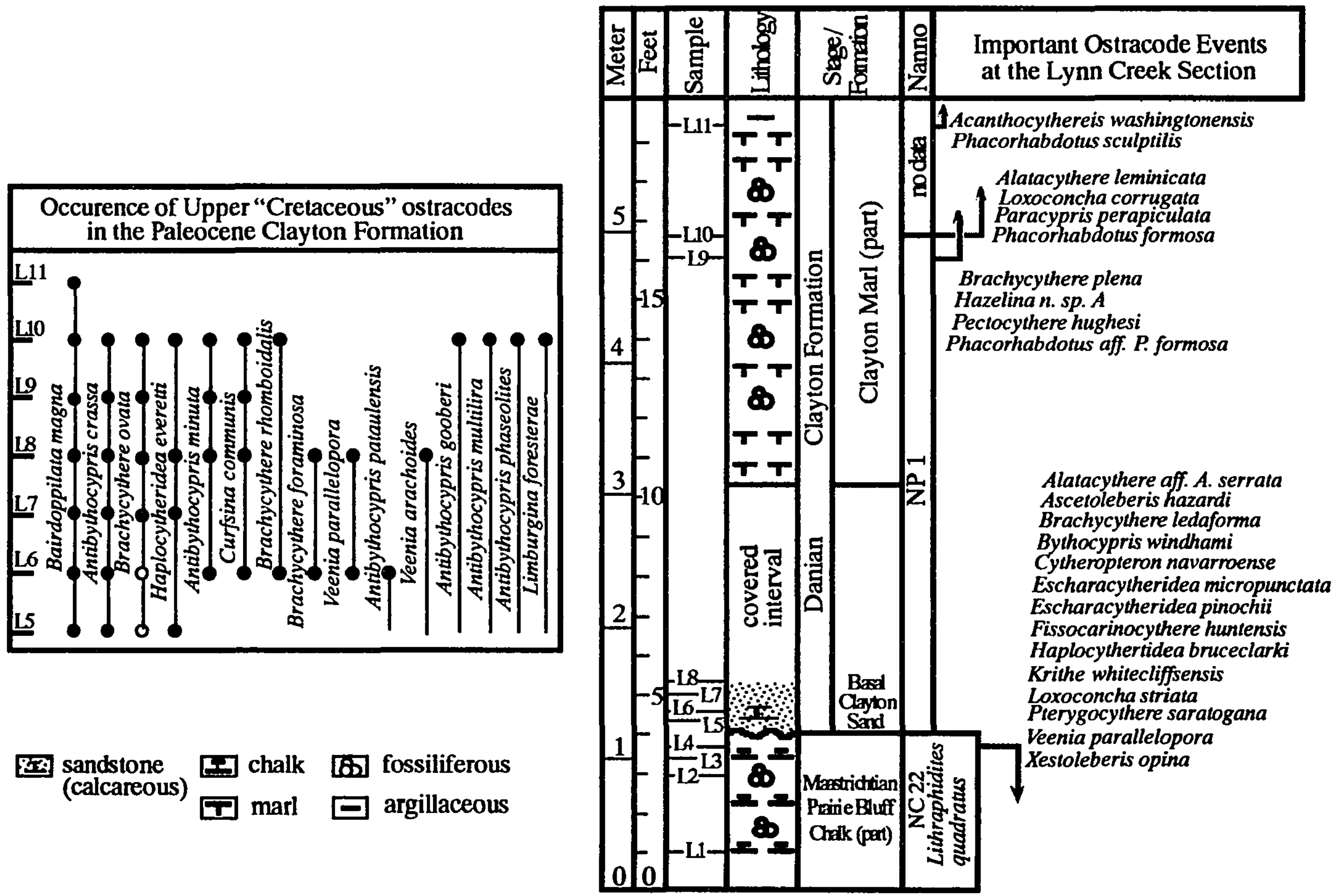


Figure 26 The Cretaceous-Tertiary section at Lynn Creek.

becomes increasingly sandy upward. The uppermost part of the Prairie Bluff has some resemblance to the Providence Formation, its eastward facies equivalent and just to the east of this location the two fromations interfinger. In this part of Lowndes County, the Prairie Bluff is about 30 to 38 meters thick. However, at its type locality at Prairie Bluff Landing along the Alabama River in Wilcox County, the Prairie Bluff is only 3.6 meters thick (LaMoreaux and Toulmin, 1959; Copeland, 1968). In parts of Dallas, Wilcox and Marengo Counties, Alabama, the Prairie Bluff is locally missing due to post-depositional erosion (LaMoreaux and Toulmin, 1959; Copeland, 1968). The Prairie Bluff is typically a lithologically heterogeneous unit that consists mainly of highly fossiliferous, glauconitic, sandy marl and blue grey, fossiliferous, dense, so-called chalk (Monroe, 1941; Russell and others, 1983). The unit rests disconformably upon the Ripley Formation. Disconformably overlying on the Prairie Bluff Formation is the Clayton Formation. The Clayton Formation at Braggs, as well as in Wilcox County, Alabama, is divided into the lower Pine Barren Member and the upper McBryde Limestone Member. The Pine Barren is Danian in age and consists of interbedded, glauconitic, fossiliferous, calcareous sand, calcareous silt and clay, and sandy limestone (Copeland, 1968; Mancini and Tew, 1989).

Because an erosional unconformity separating the Prairie Bluff and the Clayton Formation at Braggs is less obvious than at other eastern Gulf Coastal Plain K-T boundary sections, there are different interpretations as to placement of the contact between Prairie Bluff and Clayton Formations, and Cretaceous and Tertiary as well. Copeland and Mancini (1986) placed the contact between the Prairie Bluff and Pine Barren Member of Clayton Formation as well as the Cretaceous and Tertiary contact within an indurated limestone bed (bed 3, Figure 24). Based on calcareous nannofossils, Donovan and others (1988) placed the K-T boundary at the base of bed 6. However, recent studies have shown that the contact between the Cretaceous and

Tertiary as well as the Prairie Bluff and Clayton Formation is at the top of bed 2, which is the top of the Prairie Bluff (Mancini and others, 1989; Habib and others, 1992; Olsson and Lui, 1993).

To the west of Braggs, smaller outcrops that include the K-T boundary are exposed in a streamcut along Shell Creek in Wilcox County, and in a roadcut south of Lynn Creek in Noxubee County, Mississippi (Figures 25 and 26). The Maastrichtian Prairie Bluff at Shell Creek consists of 1.8 meters of dense fossiliferous chalk and below that 0.6 meters of highly fossiliferous, glauconitic, sandy chalks. At Lynn Creek the Prairie Bluff consists of only dense fossiliferous chalk. At these two locations the Prairie Bluff is unconformably overlain by a sand unit informally known as the Clayton basal sand. This thin, discontinuous, irregularly bedded sand, which generally grades upward into a Clayton sandy marl or limestone bed, also occurs in K-T sections at Moscow Landing along the Tombigbee River, Sumter County, Prairie Bluff Landing along the Alabama River, Wilcox County, and Mussell Creek, Lowndes County (Mancini and others, 1989). This unit is absent at the Braggs section. In Donovan and others (1988) the Clayton sand is assigned to the Cretaceous. Reworked Cretaceous maco- and microfossils also have been recovered from the Clayton sand (Mancini and others, 1989). However, the recovery of diagnostic Danian fossils from the sand by several workers (LaMoreaux and Toulmin, 1959; Mancini and others, 1989; Liu and Olsson, 1992; Habib and others, 1992) indicates that the sand is of Paleocene age.

The origin of this unusual sand unit is still uncertain. It has been interpreted to be a noncatastrophic lowstand-shelf, incised-valley-fill deposit (Mancini and others, 1989; Savrda, 1993). Recently, clastic beds that have been interpreted to be impact-caused-tsunami-generated units were reported from K-T boundary sections around Gulf of Mexico rim (Smit and others, 1992; Smit and others, 1994). These interpretations, along with the presence of objects interpreted to be altered impact spherules in the basal Clayton sand at Shell Creek (Pitakpaivan and Hazel, 1992; Pitakpaivan and others, 1994), suggest that slow deposition as valley fill may not be the case. The significance of the proximity of the Gulf Coast K-T sections to the proposed Chicxulub impact crator at the Yucatan Peninsula of Mexico (Hildebrand and others, 1991) is, as mentioned above, resulting in renewed interest in the Gulf Coast K-T boundary sections, particularly the Clayton sand itself (Smit and others, 1994; Habib, 1994; Olsson and Liu, 1994).

Studies of K-T boundary intervals generally are complicated by different interpretations of where the boundary is to be placed. However, according to the International Commission on Stratigraphy of International Union of Geological Sciences, the K-T boundary Global Stratotype Section and Point was designated to be at the base of the black clay layer at El Kef section, Tunisia (Cowie and others, 1989). The K-T boundary Global Stratotype Section and Point was defined as being at a lithologic boundary that marks the change between hemipelagic upper Maastrichtian marl and the black boundary clay. Global correlation of K-T boundary sections based on such lithologic criteria is limited. Planktonic micropaleontological events at El Kef should serve to correlate the boundary interval with other nearby and distant sections. However, interpretation of the micropaleontology of the boundary interval at El Kef is controversial.

Definitions of the K-T boundary based on paleontological criteria places the K-T boundary at either the mass disappearance of most Cretaceous species or the first occurrence of Paleocene species (Berggren and Miller, 1988; Keller, 1989) are widely used. These two datum planes, however, are not synchronous. At El Kef, Late Cretaceous planktonic foraminiferal abundance abruptly drops at the same level as the lithologically defined K-T boundary (Liu and Olsson, 1992; Smit, 1982). The first occurrence of Paleocene species on the other hand was observed higher in the section (Smit, 1982; Keller, 1988; Liu and Olsson, 1992). The interval that is bounded by these two planktonic foraminiferal datums was used to define a biozone, P0, by Smit (1982). The placement of the K-T boundary using paleontological criteria, at least as interpreted by Smit (1982), therefore should be at the level of the mass disappearance of Late Cretaceous planktonic foraminiferal species.

It should be pointed out that microspherules, interpreted to be of impact origin, occur in the clay layer at El Kef (Smit and Romein, 1985). The clay layer was recognized as the extraterrestrial component (ETC) – a microspherule-rich layer that was consistently found in the K-T boundary event sequence worldwide (Smit and Romein, 1985). Pseudomorphs of such microspherules also occur in the basal Clayton sand (Pitakpaivan and Hazel, 1992; Pitakpaivan and others, 1994). If the Clayton sand can be constrained paleontologically to be in the K-T boundary interval, which it can, then these spherules can be interpreted to be a chronostratigraphic marker event. This indicates that the basal Clayton sand correlates with the basal boundary clay at the boundary stratotype at El Kef represents the beginning of the Tertiary.

MATERIALS AND METHODS

A total of 41 samples of the Prairie Bluff and Clayton formations from the three locations were studied. Table 13 gives the locality data and stratigraphic positions. Of these, 10 samples from Shell Creek and seven samples from Lynn Creek section were analyzed for calcareous nannofossils by Dr. James Pospichal of Florida State University. For the ostracode analyses, samples were gently disaggregated into small pieces (about 1.2 X 1.2 X 1.2 centimeters), which then were soaked for several hours in a dilute solution of sodium bicarbonate. They were then washed on a 74-micron screen (sieve #200), dried at 50° C for several hours in an oven, dry sieved on a 177-micron screen (sieve # 80), and randomly picked for at least 500 ostracode specimens.

Both single valves and whole carapaces, juveniles and adults, males and females were picked. Ostracode specimens were counted in a conventional manner – a single valve is counted as one specimen, and a whole carapace is counted as two. Therefore the number of individual ostracode organisms represented is less than the number of specimens recorded. A total of 10,619 specimens were examined with a stereomicroscope. Tables 14 to 16 lists relative abundance of the species present.

Species diversity was calculated to evaluate paleoecologic conditions. The most basic measure of species diversity is S, which is simply the number of species observed in a sample (Gibson and Buzas, 1973). The most widely used diversity index is the Shannon-Wiener information function, H. It is dependent not only on the number of species, but also on the relative abundance of species (Gibson and Buzas, 1973). It is given by the equation: $H = -\Sigma\, p_i \ln p_i$ where p_i is the proportion of the ith species (MacArthur and MacArthur, 1961; Pielou, 1966; Gibson and Buzas, 1973).

BRAGGS SECTION

Table 14 gives the relative abundances of species that were found in sample from the roadcut sections near Braggs. Figure 27 shows a diversity-trend-curve of ostracodes at this composite section. The main constituents of the ostracode assemblages from the basal part to the uppermost part changes slightly. In the basal part of the Prairie Bluff , Haplocytheridea everetti, Cytherella spp., Bairdoppilata magna, Brachycythere ovata, Brachycythere rhomboidalis and Curfsina communis are the common species; whereas Ascetoleberis hazardi, Brachycythere ovata, Brachycythere rhomboidalis, Cytherella spp. and Escharacytheridea micropunctata are common in the middle part. In the uppermost part, Bairdoppilata magna, Brachycythere ovata, Brachycythere rhomboidalis and Cytherella spp. are common. It should be pointed out that four species were found to be restricted to the basal Prairie Bluff (samples B1-B3), 14 species to the middle part (samples B4-B8), and 27 species to the uppermost part (samples B9-B13). On the other hand, 19 species, including Amphicytherura curta, Antibythocypris gooberi, Ascetoleberis hazardi, Bairdoppilata magna, Brachycythere foraminosa s.l., Brachycythere ledaforma, Brachycythere ovata, Brachycythere rhomboidalis, Curfsina communis, Cytherella spp., Cytherelloidea bicosta s.l., Escharacytheridea magnamandibulata, Fissocarinocythere huntensis, Haplocytheridea everetti, Krithe whitecliffsensis, Limburgina foresterae, "Planileberis" cf. "P." costatana, Pterygocythere saratogana and Xestoleberis opina, were found throughout the Prairie Bluff. The ostracode assemblage suggest the Prairie Bluff was deposited in normal-marine offshore, shallow shelf environment.

The Prairie Bluff samples can be assigned to the biochronozone of the Veenia parallelopora Zone of Pitakpaivan and Hazel (1994), although the nominate species is present only in the uppermost part of the Prairie Bluff in central and eastern Alabama. The biochronozonal placement is indicated by the presence of the characterizing species Brachycythere foraminosa s.l. throughout the unit. It needs to be pointed out that in the study by Smith (1978) at this locality, no occurrence of V. parallelopora was reported. As mentioned, this species is not a common form in this area. The inconsistency of its presence is possibly due both to its general uncommonness and perhaps sample size. The use of the Shannon-Wiener information function minimizes the influence of rarity and sample size. The diversity-trend curve shows a slight fluctuation upward (Figure 27). In general, H shows increasing values from ≤ 2.6 in the basal to middle Prairie Bluff to ≥ 2.600 in the middle to uppermost Prairie Bluff. A value of 2.8 was obtained for a sample just below the top of the formation. Therefore, no gradually declining trend in ostracode diversity was observed in the Prairie Bluff at Braggs. Of the 46 Cretaceous species found in the uppermost Prairie Bluff samples (7.6 cm below the boundary), 21 (46%) of them were found in the Clayton at this locality.

In the lowest bed, bed #3, of the Clayton Formation, no ostracodes were recovered due to cementation, recrystallization and dissolution. The ostracode assemblage of the lowermost part of the Clayton (samples B14-B17) was dominated by a component similar that of the uppermost Prairie Bluff including Bairdoppilata magna, Cytherella spp. and Brachycythere ovata (ridge form). This form of Brachycythere ovata is a transitional form between the Cretaceous species, Brachycythere ovata, and the early Tertiary species, Brachycythere plena. This transitional form was first observed in sample B10, which is 76.0 cm below the K-T boundary. Above this sample incoming elements gradually start to appear. These are Opimocythere aff. O. hazeli, Haplocytheridea sp. A and Pectocythere hughesi. Relative abundance of the incoming species shows an increasing trend that fluctuated slightly near the K-T boundary, but then became steady (Figure 28). The established Cretaceous assemblage was gradually replaced up section by incoming species. As shown in Figure 24, Bairdoppilata magna is the most persistent Cretaceous species and Brachycythere ovata (transitional form) is the last surviving "Cretaceous" species to disappear. This transitional form shows an increasing, but fluctuating trend in abundance across the boundary (Figure 28).

In the lower part of the Clayton (samples B18-21), Brachycythere plena, Opimocythere aff. O. hazeli, Opimocythere hazeli, Bairdoppilata magna, Bairdia sp. 2 and Cytherella spp. are common; whereas the middle to upper part of the Clayton (samples B22-26) is dominated by a characteristic early Teriary fauna including Acanthocythereis washingtonensis, Brachycythere plena, Cytherella spp., Hermanites gibsoni, Phractocytheridea ruginosa and Haplocytheridea fornicata. Although, no ostracode zones have been established for this interval, the presence of the transitional form of Brachycythere ovata suggests the presence of very early Teriary deposits. The mixed assemblage of Cretaceous specimens with the incoming ones results in a

Table 13 List of samples used in this study. The Cretaceous-Tertiary contact at the Braggs section is between bed#2 and bed#3 (see Figure 24 for illustration of the section and bed nomenclature established by Copeland and Mancini, 1986). The Cretaceous-Tertiary contact at Shell Creek and Lynn Creek is between the Prairie Bluff Chalk and the Clayton basal sand (see Figures 25 and 26 for illustrations of these sections).

Sample location 1A	
Exposures in roadcut on Alabama State Highway 263 about 4.8 kilometers southeast of its intersection with County Road 7 and Alabama Highway 21 just west of Braggs, Lowndes County, Alabama.	
Sample no.	Stratigraphic position
B1	basal Prairie Bluff, between 0 - 0.9 meters above Ripley-Prairie Bluff contact
B2	basal Prairie Bluff, about 2.7 meters above Ripley-Prairie Bluff contact
B3	basal Prairie Bluff, about 3.3 - 4.2 meters above Ripley-Prairie Bluff contact

Sample location 1B	
Exposures in roadcut on Alabama State Highway 263 about 6.7 kilometers southeast of its intersection with County Road 7 and Alabama Highway 21 just west of Braggs, Lowndes County, Alabama. This exposure cannot be precisely related to either the Ripley-Prairie Bluff or Prairie Bluff-Pine Barren contacts, but it is stratigraphically between locations 1A and 1C.	
Sample no.	Stratigraphic position
B4	Prairie Bluff Chalk, about 0.9 meters above base of exposure
B5	Prairie Bluff Chalk, about 2.7 meters above base of exposure
B6	Prairie Bluff Chalk, about 3.6 - 6.1 meters above base of exposure
B7	Prairie Bluff Chalk, about 6.4 - 7.6 meters above base of exposure
B8	Prairie Bluff Chalk, about 8.2 - 9.7 meters above base of exposure

Sample location 1C	
Exposures in roadcut on Alabama State Highway 263 about 7.4 kilometers southeast of its intersection with County Road 7 and Alabama Highway 21 just west of Braggs, Lowndes County, Alabama.	
Sample no.	Stratigraphic position
B9	Prairie Bluff Chalk, about 1.4 meters below the Cretaceous-Tertiary contact
B10	Prairie Bluff Chalk, about 0.76 meters below the Cretaceous-Tertiary contact
B11	Prairie Bluff Chalk, about 0.23 meters below the Cretaceous-Tertiary contact
B12	Prairie Bluff Chalk, about 0.15 meters below the Cretaceous-Tertiary contact
B13	Prairie Bluff Chalk, about 0.08 meters below the Cretaceous-Tertiary contact
B14	Pine Barren Member of the Clayton Formation, 15 centimeters above the contact
B15	Pine Barren Member of the Clayton Formation, 45 centimeters above the contact
B16	Pine Barren Member of the Clayton Formation, 76 centimeters above the contact
B17	Pine Barren Member of the Clayton Formation, 1.1 meters above the contact
B18	Pine Barren Member of the Clayton Formation, 1.2 meters above the contact
B19	Pine Barren Member of the Clayton Formation, 1.4 meters above the contact
B20	Pine Barren Member of the Clayton Formation, 1.5 meters above the contact
B21	Pine Barren Member of the Clayton Formation, 2.3 meters above the contact
B22	Pine Barren Member of the Clayton Formation, 5.7 meters above the contact

table con'd.

B23	Pine Barren Member of the Clayton Formation, 7.1 meters above the contact
B24	Pine Barren Member of the Clayton Formation, 8.6 meters above the contact
B25	Pine Barren Member of the Clayton Formation, 10.8 meters above the contact
B26	Pine Barren Member of the Clayton Formation, 12.3 meters above the contact

Sample location 2	
Exposures on a streambank along Shell Creek in Wilcox County, Alabama.	
Sample no.	Stratigraphic position
S1	Prairie Bluff Chalk, about 2.1 meters below contact
S2	Prairie Bluff Chalk, about 0.15 meters below contact
S3	Prairie Bluff Chalk, about 5.0 centimeters below contact
S4	Prairie Bluff Chalk, about 2.5 centimeters below contact
S5	Clayton basal sand, about 5.0 centimeters above the contact
S6	Clayton basal sand, about 0.2 meters above the contact
S7	Clayton basal sand, about 0.43 meters above the contact
S8	Clayton basal sand, about 0.5 meters above the contact
S9	Clayton basal sand, about 0.66 meters above the contact
S10	Clayton basal sand, about 0.78 meters above the contact
S11	Clayton basal sand, about 0.88 meters above the contact

Sample location 3	
Exposures in a roadcut south of Lynn Creek in Noxubee County, Mississippi.	
Sample no.	Stratigraphic position
L1	Prairie Bluff Chalk, base of section about 1.2 meters below the contact
L2	Prairie Bluff Chalk, about 20 - 30 centimeters below the contact
L3	Prairie Bluff Chalk, about 18 centimeters below the contact
L4	Prairie Bluff Chalk, about 7.5 centimeters below the contact
L5	Clayton basal sand, about 5 centimeters above the contact
L6	Clayton basal sand, about 15 centimeters above the contact
L7	Clayton basal sand, about 30 centimeters above the contact
L8	Clayton basal sand, about 40 centimeters above the contact
L9	Clayton marl, about 3.6 meters above the contact
L10	Clayton marl, about 3.8 meters above the contact
L11	Clayton marl, about 4.7 meters above the contact

Table 14 Relative abundance of ostracode species of the Cretaceous-Tertiary boundary section at Braggs roadcut location. ● = dominant species (> 15%), ⊙ = secondary species (5-15%), O = minor species (< 5% but found in more than one sample), X = rare species (<5% and found only in one sample) ▒ indicates specimens interpreted to be reworked (see text).

	Braggs section																									
	Prairie Bluff Chalk													Pine Barren Member Clayton Formation												
Samples	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26
Paleocene ostracodes																										
Acanthocythereis washingtonensis																						●	●	⊙	⊙	●
Bairdoppilata suborbiculata																						O	O	O		
Brachycythere plena																	⊙	●		⊙		●	●	●	O	●
Clithrocytheridea n. sp. A																									X	
Cytherella spp.																					●	⊙	⊙	⊙	O	●
Cytherelloidea sullivani																						O	O		O	O
Cytherelloidea truncata lowndesensis															⊙		O					O		O	O	
Cytheromorpha braggsensis																								O		
Cytheromorpha pittsi																								X		
Haplocytheridea n. sp. A												O	O		O											
Haplocytheridea n. sp. B																	X									
Haplocytheridea fornicata																						⊙	⊙	●	●	⊙
Hermanites cf. H. plusculmensis																	O		O		●					
Hermanites gibsoni																			O			⊙	⊙	⊙	●	
Hermanites n. sp. A																										X
Loxoconcha atlantica																								X		
Loxoconcha nuda																	O							O		

table con'd.

	Braggs section																									
	Prairie Bluff Chalk													Pine Barren Member Clayton Formation												
Samples	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26
Opimocythere aff. O. hazeli											○	⊙	○		○		○		⊙		●					
Opimocythere hazeli															○		⊙	●		●						
Opimocythere n. sp. A																									○	
Orthonotacythere cristata																						○	⊙	○	●	⊙
Ouachitaia aff. O. ruida																						○			○	
Paracypris perapiculata																	⊙					○	○		○	
Pectocythere hughesi													○				○									
Phractocytheridea ruginosa																	○				⊙	●	⊙	⊙	●	
Upper Cretaceous ostracodes																										
Alatacythere aff. A. serrata										○	⊙		○													
Amphicytherura curta	○		○	○	○	○	○	○	○	⊙	⊙	○	○		○		○									
Antibythocypris crassa							○	○		○	○	○	○		○		○									
Antibythocypris elongata								×																		
Antibythocypris fabaformis							⊙	⊙			○	○	○													
Antibythocypris gooberi	○	⊙	○		○	○	○	○		○	○	○	○		○											
Antibythocypris johnsoni													×													
Antibythocypris kiddi	○		○																							
Antibythocypris minuta					○	○	○	○	○	○	○	○	○		○		○									
Antibythocypris multilira						○	○	○				○	○													
Antibythocypris pataulensis					○			○			○															
Antibythocypris phaseolites								○				○														
Antibythocypris trisulcata										×																
Anticythereis sp. 1						○	○	○					○													
Anticythereis sp. 3				×																						

table con'd.

	Braggs section																									
	Prairie Bluff Chalk													Pine Barren Member Clayton Formation												
Samples	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26
Anticythereis sp. 4						○	○	○	○	○	○	○														
Anticythereis sp. 6						×																				
Anticythereis sp. 10									×																	
Anticythereis sp. 11													×													
Anticythereis sp. 14										○	○		○													
Anticythereis sp. 16					×																					
Anticythereis sp. 17							○	○		○	○															
Anticythereis cf. A. sp. 4											○		○													
Anticythereis copelandi						○	○	○			○															
Argilloecia sp. 1										×																
Argilloecia sp. 2										○			○													
Ascetoleberis hazardi		○	○	⊙	⊙	○	○	⊙	○		○	○														
Aversovalva fossata s.l.				○				○		○	○		○													
Bairdoppilata magna	⊙		⊙		⊙			○	⊙	⊙	⊙	●	●		●		⊙	●	⊙	●	●					
Bairdia sp.1											○						○		⊙							
Bairdia sp.2																	⊙	●		●						
Bairdia sp. 3										○			○													
Brachycythere foraminosa s.l.	○	⊙	○		○	○	⊙	⊙	⊙	⊙	○		○		○											
Brachycythere ledaforma		⊙	○	○	○	○	○			○	○		○													
Brachycythere ovata	⊙	○	●	⊙	●	○	○	○	●	⊙	●	●	⊙													
Brachycythere ovata (ridge form)										○	○	⊙	○		●		⊙		●			○				
Brachycythere rhomboidalis	⊙	⊙	⊙	●	⊙	●	⊙	○	●	○	⊙	⊙	⊙		○		⊙									
Bythocypris windhami	○								○	○			○		○											
Curfsina communis	○	●	⊙	○	⊙	⊙	○	○	○	○	⊙	⊙	○		○		○		⊙							

table con'd.

	Braggs section																									
	Prairie Bluff Chalk													Pine Barren Member Clayton Formation												
Samples	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26
Cushmanidea sp. 1						○	○	○																		
Cushmanidea sp. 5										×																
Cytherella spp.	●	●	●	⊙	⊙	●	●	⊙	⊙	●	●	⊙	●		⊙		●	●	●	⊙						
Cytherelloidea aff. C. spiralia				○	○		○	○																		
Cytherelloidea aff. C. tolletensis																			⊙							
Cytherelloidea austinenesis			×																							
Cytherelloidea bicosta s.l.		○	○	○	○	○	○	○	○	○	○	⊙	○													
Cytheromorpha arbenzi				×																						
Cytheropteron castorensis						○				○			○		○											
Cytheropteron cf. C. castorensis								×																		
Cytheropteron cf. C. type A of Smith								○		○																
Cytheropteron coryelli				○		○		○		○			○													
Cytheropteron sp. A													×													
Cytheropteron navarroense		○									○															
Cytheropteron TYPE B															×											
Escharacytheridea magnamandibulata			○	○								○														
Escharacytheridea micropunctata				⊙	○	●	●	⊙	○																	
Escharacytheridea pinochii										○	⊙		○		○											
Eucythere sohli	○									○			○													
Eucytherura aff. E. reticulata										○	○		○				○									
Eucytherura reticulata													○				○									
Fissocarinocythere huntensis			○		○	○		○	○	○	○	○	○													
Fissocarinocythere pidgeoni				○	○	○	○	○																		
Haplocytheridea bruceclarki										○	○	○	○		○											

table con'd.

	Braggs section																									
	Prairie Bluff Chalk													Pine Barren Member Clayton Formation												
Samples	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26
Haplocytheridea everetti	⊙	⊙	⊙	⊙	o	o	o	o	⊙			o														
Haplocytheridea globosa		o	o					o																		
Haplocytheridea renfroensis				o		⊙	o	⊙	o			o														
Krithe whitecliffsensis	⊙			o			o			o	o															
Limburgina foresterae	o		o	o	o	o	o	o	o	o	o	o	o				o									
Loxoconcha clinocosta										o	o		o		o		×									
Loxoconcha digitinota		×											·													
Loxoconcha erecticosta											o		o													
Loxoconcha fletcheri										×																
Loxoconcha minardi							×																			
Loxoconcha striata		o								o	o		o													
"Monoceratina" aff. M. acanthoptera										×																
"Monoceratina" sp. B							×																			
"Monoceratina" sp. E										×																
Orthonotacythere hannai				o	o	o	o	o	o	o	o	o	o													
Paracypris sp. 1	×																									
Paracypris sp. 2	o						o	o																		
Paracypris sp. 3										o			o				o		o							
"Planileberis" cf. "P." costatana	o		o		o			o		o	o	o	o		o		o									
Platycosta lixula				⊙	o	o	o	o		o	o		o													
Polylophus asper										o	o															
Pterygocythere saratogana			o	o	o	o	o	o	o	o	o	o	o													
Soudanella sp. A							×																			
Soudanella sp. B								×																		

table con'd.

	Braggs section																									
	Prairie Bluff Chalk													Pine Barren Member Clayton Formation												
Samples	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26
Soudanella parallelopora							O	O			O		O													
Veenia adkinsi					O		O		O	O	O															
Veenia parallelopora										O	O															
Veenia ponderosana								×																		
Xestoleberis sp. 3										O			O													
Xestoleberis opina		O						O	O	⊙	O	O	⊙		O											
Xestoleberis seminulata				O				O	O																	

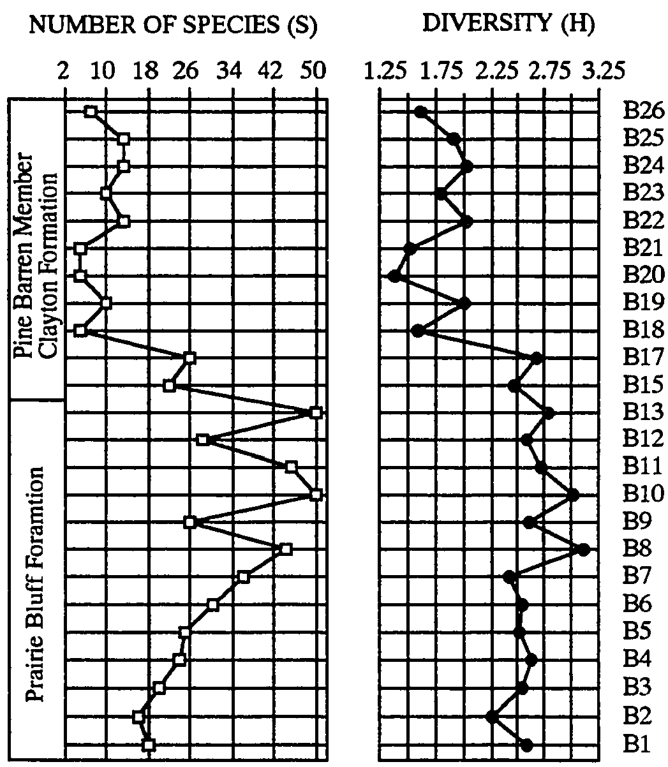


Figure 27 A trend curve of number of species (S) and diversity (H) at Braggs section.

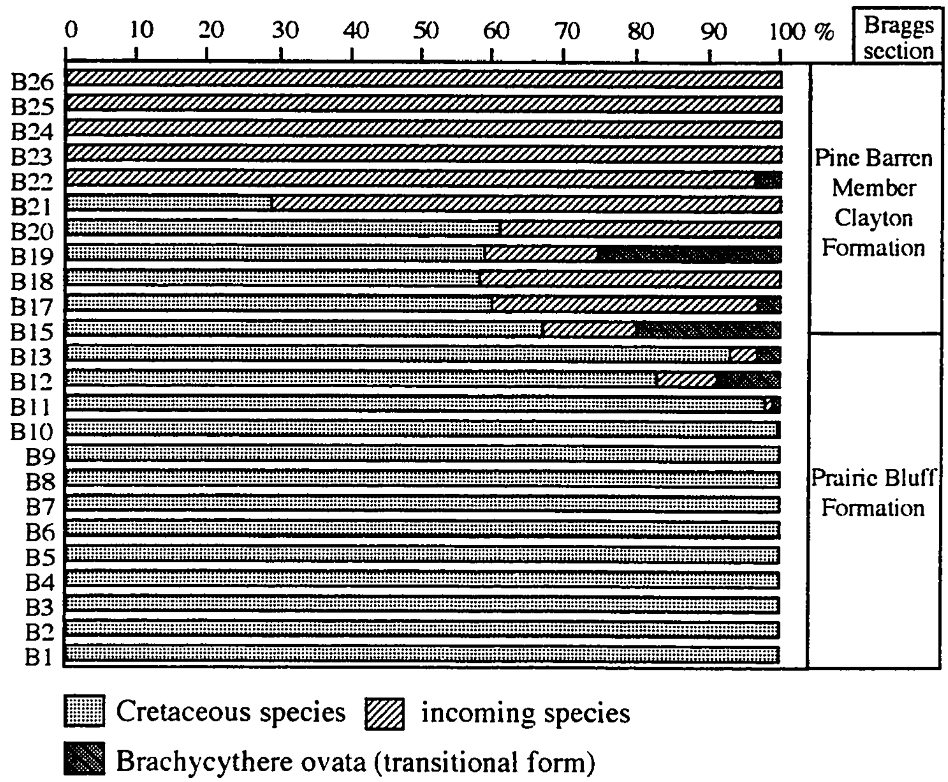


Figure 28 The relative abundance of Upper Cretaceous species, incoming species and <u>Brachycythere</u> <u>ovata</u> (transitional form) across the Cretaceous-Tertiary boundary at Braggs.

moderately high diversity index (2.5 and 2.7) in the lowest part of the Clayton. The diversity then drops to ≤ 2.0 and fluctuates slightly up section (Figure 27). However, the diversity index never becomes as high as in the uppermost Prairie Bluff. Most of the "Cretaceous" species found in the lowermost Clayton are considered to be survivors because of the following reasons:

1) These species exhibit the same degree of preservation as the incoming species, without any indication of abrasion or carapace color differences.

2) The main component of the surviving species include most of the common species that have long ranges and were found throughout the Prairie Bluff.

3) As shown in Figure 27, after a sharp drop in the relative abundance of Cretaceous species at the K-T boundary, the surviving species exhibit a gradual decline in relative abundance until they totally disappear by extinction or by evolving into new forms. If these were reworked, there should be an unusually high abundance of "Cretaceous" species near the boundary.

However, very few surviving specimens show any indication of reworking that possibly could have been caused by a short-term fluctuation of sea-level.

SHELL CREEK SECTION

Table 15 shows the relative abundance of species in samples collected at Shell Creek, Wilcox Co., Alabama. Figure 29 shows the diversity-trend curve for the ostracodes at this locality. The main constituents of the ostracode assemblage in the lower part of the section differ slightly from that of the upper part. In the lower part of the Prairie Bluff sample (S1), which contain numerous macrofossils, Bairdoppilata magna is the dominant species; whereas Amphicytherura curta, Antibythocypris gooberi, Antibythocypris minuta, Curfsina communis, and Cytherella spp. are common species. In the upper part, which contains no observed macrofossils, Cytherella spp. is the only dominant species, except for one sample (S2) that contains Bairdoppilata magna as another dominant species. The ostracode assemblage suggests that the Prairie Bluff was deposited in an offshore normal-marine shallow shelf environment. Biostratigraphically it can be assigned to the Veenia parallelopora Zone. As shown in Figure 29, diversity decreases up section. The lower macrofossiliferous-rich part of the Prairie Bluff has a high H value of 2.7. The upper nonmacrofossiliferous has a relatively lower H value of 2.4-2.5. Among 48 species found in the Prairie Bluff, 24 of them (50%) were observed in the Clayton. However, because of the poor state of preservation, it is not possible in nearly all cases to determine whether the Cretaceous specimens found in the Clayton are reworked or examples of surviving species.

The Clayton basal sand contains no incoming species (Figure 30). The ostracode assemblage is rather unusual because it contains 29 "Cretaceous" species, six of which were not found in the underlying Prairie Bluff at this locality. These taxa are Anticythereis sp. 15, Anticythereis copelandi, Bairdia sp. 2, Cytherelloidea spiralia, Macrocypris sp. 4 and Orthonotacythere hannai. The most abundant "Cretaceous" species found in the sand are Bairdoppilata magna, Cytherella spp., Brachycythere. ovata, Curfsina. communis, Haplocytheridea bruceclarki, and Haplocytheridea everetti. This combination of species suggests reworking or redepositing of the sand unit because the abundant forms not only include the common species that were found throughout the underlying Prairie Bluff, but also the less common species. Further, the diversity trend curve for the Clayton sand shows a fluctuating, but declining trend. The degree of fluctuation suggests that the assembalge is not indigenous. However, it is also possible that the observed faunal change could be due to a substrate change from carbonate dominated mud to sand. This is because species of Anticythereis and Orthonotacythere hannai were found to be more common in the clastic-dominated units than in carbonate-dominated units (see Chapter 4). It is in this sand (samples S5 to S10)

Table 15 Relative abundance of ostracode species of the Cretaceous-Tertiary boundary section at Shell Creek location. ● = dominant species (> 15%), ⊙ = secondary species (5-15%), O = minor species (< 5% but found in more than one sample), X = rare species (<5% and found only in one sample) and ░ indicates specimens interpreted to be reworked (see text).

	Shell Creek section										
	Prairie Bluff Chalk				Basal Clayton Sand						
Samples	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Upper Cretaceous ostracodes											
Alatacythere aff. A. serrata		O	O	O							
Amphicytherura curta	⊙	O		O		░⊙	░⊙			░⊙	░⊙
Antibythocypris crassa	O						░⊙			░⊙	░⊙
Antibythocypris fabaformis	O										░⊙
Antibythocypris gooberi	⊙	O	O	O							
Antibythocypris minuta	⊙		O			░⊙	░⊙			░⊙	░⊙
Antibythocypris pataulensis	O									░⊙	
Anticythereis sp. 4	O										
Anticythereis sp. 14	X										
Anticythereis sp. 15						░X					
Anticythereis copelandi						░X					
Ascetoleberis hazardi	O	O	O	O							
Bairdoppilata magna	●	●	O	O	░⊙	░●	░●	░⊙	░●	░●	░⊙
Bairdia sp. 2					░⊙	░⊙					
Bairdia sp. 3	X										
Brachycythere foraminosa s.l.	O		O	O	░⊙				░⊙		░⊙
Brachycythere ledaforma		O	O	⊙		░⊙					
Brachycythere ovata	O	⊙	O	⊙	░⊙	░⊙	░⊙		░●	░⊙	
Brachycythere ovata (ridge form)			O	O		⊙	░O	░O	░O		
Brachycythere rhomboidalis	O	O	O	O		░O		░O	░O	░⊙	
Bythocypris windhami		O	O	O		░O	░O		░⊙	░O	
Curfsina communis	⊙	O	O	O	░⊙		░⊙	░O	░O	░O	░●
Cytherella spp.	⊙	●	●	●	░●	░⊙	░●	░⊙	░●	░●	░●
Cytherelloidea aff. C. austinenesis	O	O								░O	
Cytherelloidea bicosta s.l.	O	O	⊙	⊙	░⊙	░O		░⊙		░⊙	░O
Cytherelloidea crafti		O									
Cytherelloidea spiralia					░X						
Cytheropteron coryelli			O	O							
Cytheropteron navarroense	O										
Escharacytheridea pinochii	O										
Eucythere sohli			X								
Eucytherura aff. E. reticulata			X								
Fissocarinocythere huntensis	O	O	O	O							
Haplocyhteridea bruceclarki	O	⊙	O	O		░⊙		░●		░O	
Haplocyhteridea everetti	O					░⊙		░●	░⊙		

table con'd.

	Shell Creek section										
	Prairie Bluff Chalk				Basal Clayton Sand						
Samples	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Krithe whitecliffsensis		O	O	O							⊙
Limburgina foresterae	O										
Macrocypris sp.1		O	O	O							
Macrocypris sp.4					⊙					⊙	
"Monoceratina" aff. "M." umbonata			O	O							
"Monoceratina" sp. B			X								
"Monoceratina" sp. C			O	O							
Monoceratina protheroensis			X								
Orthonotacythere hannai					X						
Paracypris sp. 2			X								
Paracypris sp. 3		O	O	O							
"Planileberis" cf. "P." costatana	O		O			⊙		O			
Platycosta lixula		O	O			⊙					
Pterygocythere saratogana		O	O	⊙							
Veenia adkinsi	O										
Veenia parallelopora			O	O				⊙			
Xestoleberis sp. 3		X									
Xestoleberis opina	O	⊙	O		⊙		⊙	⊙			
Xestoleberis seminulata			O	O				⊙			

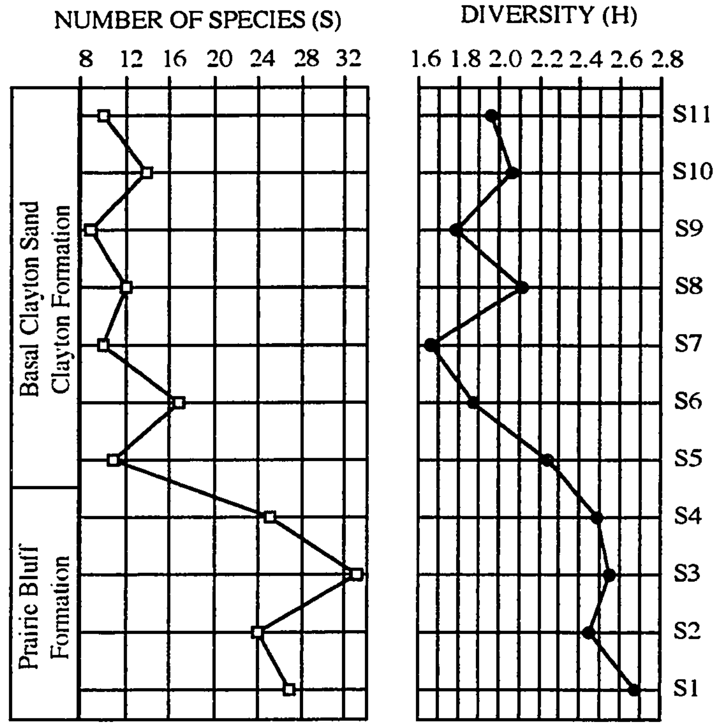


Figure 29 A trend curve of number of species (S) and species diversity (H) at the Shell Creek section.

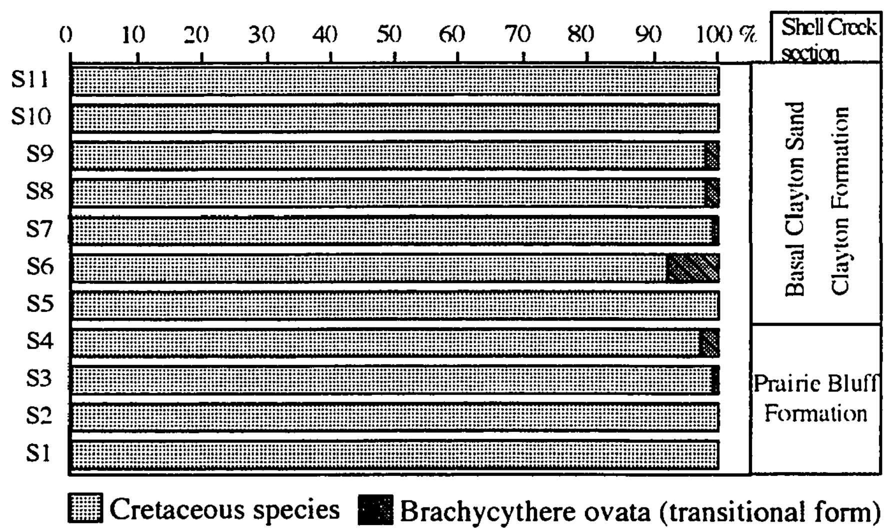


Figure 30 The relative abundance of Upper Cretaceous species and Brachycythere ovata (transitional form) across the Cretaceous-Tertiary boundary at the Shell Creek section.

that pseudomorphs of impact spherules were found (Pitakpaivan and Hazel, 1992; Pitakpaivan and others, 1994).

The nannofossil analysis indicated that the uppermost Prairie Bluff is within the upper Maastrichtian Micula murus Zone (NC23). Unlike the Braggs section, the topmost Maastrichtian zone marker, Micula prinsii was not found (Figures 24, 25); thus indicating the presence of a minor disconformity and the removal of the youngest part of the Prairie Bluff. However, the nannofossil results show that the magnitude of the disconformity is much less than previously thought (see Mancini and others, 1989; Pitakpaivan and Hazel, 1994). The nannofossil assemblage of the Clayton sand contains no diagnostic species of the lowermost Tertiary zone, NP1. Neither survivor species nor Tertiary species were recovered. Only few reworked Cretaceous species were found (Figures 24, 25; J. Pospichal, written communication, 1993).

LYNN CREEK SECTION

Table 16 shows the relative abundance of the ostracode species that were found in a roadcut section south of Lynn Creek, Noxubee Co., Mississippi. Figure 31 gives diversity-trend curve for the ostracodes. The Prairie Bluff at this locality is dominated by Cytherella spp. throughout, and contains Brachycythere ovata, Brachycythere rhomboidalis and Haplocytheridea bruceclarki as common components. The assemblage suggests that the Prairie Bluff can be assigned to the chronozone of the Veenia parallelopora Zone, and was deposited in a normal-marine, offshore shallow shelf environment. As shown in Figure 31, the diversity curve exhibits a slight increase upsection. The uppermost part of the Prairie Bluff has a moderately high H value of 2.6, and the first appearance of the transitional form of Brachycythere ovata occurs. Of the 26 species occurring in the Prairie Bluff, 18 (69%) were not found above the K-T boundary. No gradual pattern of declining diversity was observed in the Prairie Bluff before the boundary. The S and H drop sharply when the boundary is crossed. Seven "Cretaceous" species were found in the Clayton basal sand. However, their poor preservation prohibit a differentiation between reworked and survivor taxa.

In the lowermost part of basal sand, H has a value of 1.2, which is low. It gradually increases, but fluctuates. In the sand, no incoming species were found, and the main components of the assemblage are Cretaceous taxa. Bairdoppilata magna dominates throughout, and Brachycythere ovata, Brachycythere vata (transitional form), Cytherella spp. and Haplocytheridea everetti are common. Among these, only Brachycythere ovata and Cytherella spp. were dominant species in the underlying Prairie Bluff. Of 13 Cretaceous species found in the sand, five (38%) were not observed in the underlying Prairie Bluff at this locality. These are Antibythocypris crassa, Antibythocypris minuta, Antibythocypris pataulensis, Haplocytheridea everetti and Veenia arachoides. It should be pointed out that the species of Antibythocypris have been observed to be common in relatively near-shore shallow shelf environment (see Chapter 4). This type of assemblage is similar to that observed in the basal sand at Shell Creek which is possibly caused by either a change in substrate or a reworking or redeposition of the assemblage. The spherule pseudomorphs were found in the basal sand (samples L5 to L8) but are more poorly preserved and less obvious than that at Shell Creek (Pitakpaivan and Hazel, 1992; Pitakpaivan and others, 1994).

Incoming species appear gradually in the Clayton marl (Figure 32). The key Tertiary species, Brachycythere plena, appears first in the marl and increases in abundance upward. Cytherella spp. is the dominant species, whereas the early form of Phacorhabdotus formosa is also common. The "Cretaceous" specimens found in the marl also include species that were not found in the underlying Prairie Bluff at this locality. However, these represent only 24% of the specimens, which is less than the proportion found in the underlying sand. Some of the "Cretaceous" species found in the marl include Bairdoppilata magna, Brachycythere ovata (transitional form),

Table 16 Relative abundance of ostracode species of the Cretaceous-Tertiary boundary section at Lynn Creek location.
● = dominant species (> 15%), ⊙ = secondary species (5-15%),
O = minor species (< 5% but found in more than one sample), X = rare species (<5% and found only in one sample) and
[ ] indicates specimens interpreted to be reworked (see text).

	Lynn Creek section										
	Prairie Bluff Chalk				Clayton Formation						
					Basal Clayton Sand				Clayton Marl		
Samples	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
Paleocene ostracodes											
Acanthocythereis washingtonensis											X
Alatacythere leminicata										O	O
Argilloecia sp. 3										X	
Brachycythere plena									O	O	●
Cytherella spp.									●	●	●
Hazelina sp. A									O		⊙
Krithe sp. A										X	
Krithe sp. B											X
Loxoconcha corrugata										O	O
Loxoconcha sp. A											X
Loxoconcha sp. C											X
Loxoconcha sp. D										O	O
Monoceratina sp. G										X	
Paracypris perapiculata										X	
Pectocythere hughesi									X		
Phacorhabdotus aff. P. formosa									●	⊙	●
Phacorhabdotus formosa										O	O
Phacorhabdotus sculptilis											X
Upper Cretaceous ostracodes											
Alatacythere aff. A. serrata	O	O	⊙	O							
Antibythocypris crassa					[⊙]	[⊙]	[⊙]	[⊙]	[O]	[⊙]	
Antibythocypris gooberi										[X]	
Antibythocypris minuta						[⊙]		[⊙]	[O]	[⊙]	
Antibythocypris multilira										[X]	
Antibythocypris pataulensis						[X]					
Antibythocypris phaseolites										[X]	
Ascetoleberis hazardi	⊙	O	O	⊙							
Bairdoppilata magna			O		[●]	[●]	[●]	[●]	●	●	●
Brachycythere foraminosa s.l.	O	O	O	O		[⊙]		[⊙]		[⊙]	
Brachycythere ledaforma	O	O	O	O							
Brachycythere ovata	●	⊙	⊙	O	[⊙]	[⊙]	[⊙]	[●]	[⊙]		
Brachycythere ovata (ridge form)				O	[●]	[⊙]	[⊙]	[⊙]	⊙	●	
Brachycythere rhomboidalis	●	⊙	⊙	⊙		[⊙]				[⊙]	

table con'd.

	Lynn Creek section										
	Prairie Bluff Chalk				Clayton Formation						
					Basal Clayton Sand				Clayton Marl		
Samples	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
Bythocypris windhami		○		○							
Curfsina communis	○	⊙	⊙	○		⊙		⊙	⊙	○	
Cytherella spp.	●	●	●	●		●	⊙	⊙			
Cytheropteron navarroense	○	○	○	⊙							
Escharacytheridea micropunctata	○	⊙	○	○							
Escharacytheridea pinochii				X							
Eucythere sohli	X										
Fissocarinocythere huntensis	○	○		⊙							
Haplocyhteridea bruceclarki	⊙	●	⊙	⊙							
Haplocyhteridea everetti					⊙		⊙	●		⊙	
Krithe whitecliffsensis	○	⊙	⊙	⊙							
Limburgina foresterae										X	
Loxoconcha clinocosta	X										
Loxoconcha striata	○	○	○	○							
"Monoceratina" aff. "M." umbonata	○	○		○							
"Monoceratina" sp. C	X										
Paracypris sp. 1				X							
Paracypris sp. 2											
Paracypris sp. 3			○								○
Pterygocythere saratogana	○	○	○	○							
Veenia arachoides								X			
Veenia parallelopora		○				⊙		⊙			
Xestoleberis opina				X							
Xestoleberis seminulata										⊙	○

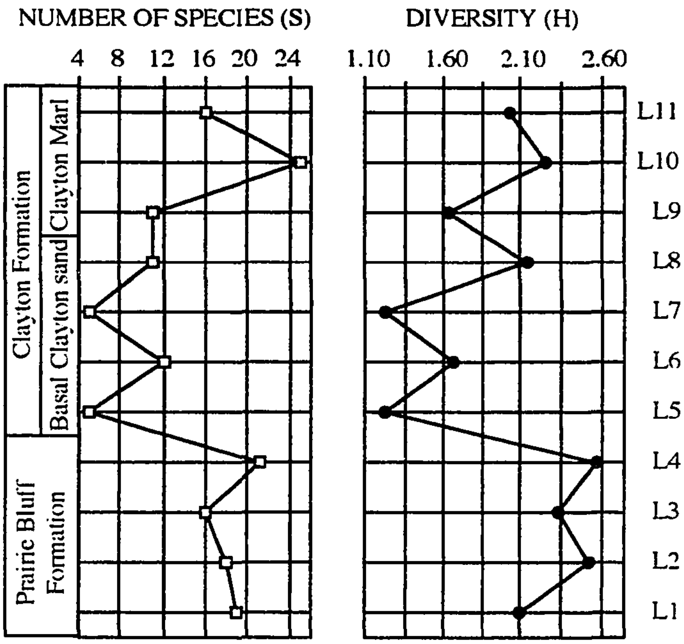


Figure 31 A trend curve of number of species (S) and species diversity (H) at the Lynn Creek section.

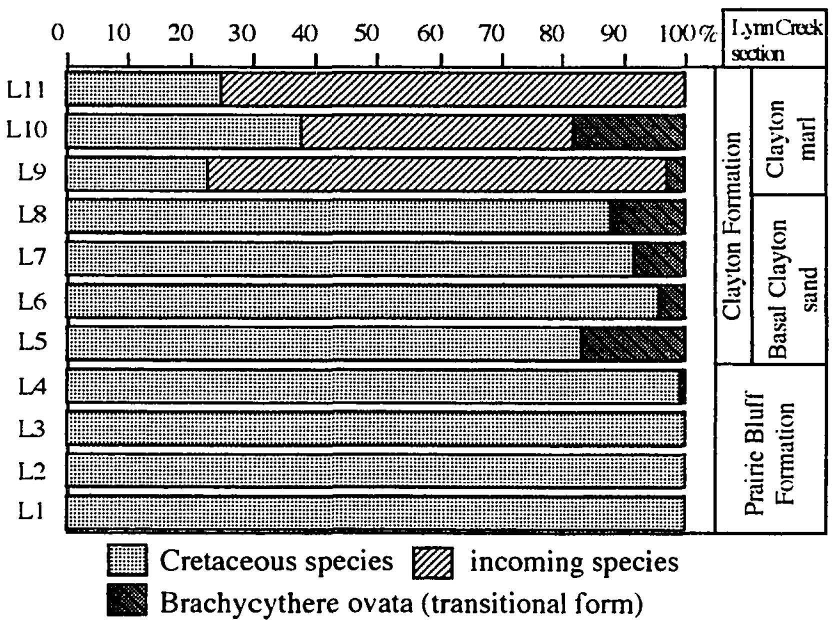


Figure 32 The relative abundance of Upper Cretaceous species, Brachycythere ovata (transitional form) and incoming species across the Cretaceous-Tertiary boundary at the Lynn Creek section.

Curfsina communis, Paracypris sp.3 and Xestoleberis seminulata are quite posssibly true surviving species because they are as well preserved as the Tertiary specimens. All but Xestoleberis seminulata were found as survivors in the Clayton at the Braggs section. Also the diversity trend fluctuates less in the marl than in the sand. H is relatively low (1.6) in the lower part of the marl, but then increases to > 2.0.

The nannofossil analysis of Lynn Creek section indicated the uppermost Prairie Bluff is within the Lithraphidites quadratus Zone (NC22). The upper Maastrichtian markers, M. murus and Nephrolithus frequens, which were found at Shell Creek, were not observed at Lynn Creek (J. Pospichal, written communication, 1993). It is possible that these key species that have been reported as rare in other sections in the region were too rare to be easily detected in the samples. If, however, the absence of these younger zonal indicators is genuine, a significant disconformity is present at Lynn Creek. In the lower part of basal sand, the Cretaceous nannofossil species drop sharply in abundance and only few rare to common reworked Cretaceous specimens were observed. A survivor species, Markalius inversus, first appears in the uppermost part of the sand unit together with common reworked Cretaceous specimens. The basal sand, thus, can be assigned to the lower part of Zone NP1. In the marl, the nannofossil assemblage shows a major change with the presence of a number of survivor and Tertiary species that are indicative of the middle to upper part of nannofossil zone NP1 (J. Pospichal, written communication, 1993).

DISCUSSION AND CONCLUSIONS

The K-T boundary sections in this study are characterized by the presence of a disconformity, the disappearance of many ostracode Cretaceous species, the presence of "Cretaceous" specimens in the Tertiary sediments, a Tertiary basal sand unit, and the occurrence of pseudomorphs of impact microspherules in the basal sand. However, not all of these elements are present at all of the K-T sections studied and, where present, their magnitudes vary from section to section. The detailed ostracode study revealed that in the study area the ostracodes were less perturbed by the event or events, at the end of the Cretaceous than were the calcareous nannofossils or planktonic foraminifers (Worsley, 1974; Thierstein, 1981; Habib and others, 1992; Olsson and Liu, 1993). Some taxa merely disappeared because they evolved into new species, for example Brachycythere ovata gave rise to Brachycythere plena, and Orthonotacythere hannai to Orthonotacythere cristata. However, some taxa, including species of Amphicytherura, Ascetoleberis, Escharacytheridea, Fissocarinocythere, Limburgina, Platycosta, Sphaeroleberis, and Veenia actually became extinct, leaving no known evolutionary descendants. Table 17 lists the disappearing species that were observed in the K-T sections in this study in comparison to those of the K-T sections in east Texas (Maddocks, 1985). Disappearing species including Alatacythere aff. A. serrata, Ascetoleberis hazardi, Cytheropteron navarroense, Escharacytheridea micropunctata, Eucythere sohli, Fissocarinocythere huntensis, Haplocytheridea globosa, Krithe whitecliffsensis, Orthonotacythere hannai, Pterygocythere saratogana and Veenia parallelopora, which occur in most of the Cretaceous samples. Therefore, the abrupt disappearance of these species together with a sharp drop in abundance of Cretaceous species can be used to characterize the K-T boundary in the Gulf Coast region. This faunal discontinuity coincides with the lithologic discontinuity between chalk and sand at Shell and Lynn Creek, and between sandy clay and limestone at Braggs.

Although the basal Clayton sand is missing at the Braggs section, the nannofossils and ostracodes indicate that the K-T section at Braggs is the most complete. The presence of the uppermost Maastrichtian and lowermost Tertiary can be recognized by a characteristic ostracode assemblage. The uppermost part of the Prairie Bluff that is assigned to the nannofossil Micula prinsii Zone is characterized by the presence of ostracodes Antibythocypris johnsoni, Cytheropteron sp.A, Eucytherura

Table 17 List of species that were found to disappear at the Cretaceous-Tertiary boundary.

Disappearing sp.	Littig Quarry	Walkers Creek	Brazos River	Shell Creek	Lynn Creek	Braggs roadcut
Alatacythere aff. A. serrata		X	X	X	X	X
Aversovalva fossata			X			X
Antibythocypris elongata						X
Antibythocypris fabaformis						X
Antibythocypris gooberi				X		
Antibythocypris johnsoni						X
Antibythocypris kiddi						X
Antibythocypris macropora		X				
Antibythocypris multilira						X
Antibythocypris pataulensis						X
Antibythocypris phaseolite						X
Antibythocypris trisulcata						X
Anticythereis copelandi						X
Ascetoleberis hazardi	X	X		X	X	X
Brachycythere foraminosa s.l.		X				
Brachycythere ledaforma					X	X
Brachycythere ovata	X	X				
Brachycythere rhomboidalis	X					
Bairdoppilata magna		X				
Curfsina communis		X				
Cytherelloidea bicosta s.l.						X
Cytheromorpha arbenzi	X					X
Cytheropteron coryelli				X		X
Cytheropteron navarroense		X		X	X	X
Escharacytheridea magnamandibulata						X
Escharacytheridea micropunctata	X		X		X	X
Escharacytheridea pinochii				X	X	
Eucythere sohli				X	X	X
Fissocarinocythere huntensis		X		X	X	X
Haplocytheridea everetti	X					X
Haplocytheridea bruceclarki					X	
Haplocytheridea globosa	X	X				X
Haplocytheridea renfroensis	X					X
Krithe whitecliffsensis		X		X	X	X
Loxoconcha striata					X	X
"Monoceratina" aff. "M". umbonata				X	X	
Orthonotacythere hannai		X	X			X
Paracypris sp. 1					X	X
Platycosta lixula		X				X
Pterygocythere saratogana		X		X	X	X
Phacorhabdotus tridentus		X				
Veenia adkinsi				X		X
Veenia arachoides		X	X			
Veenia parallelopora	X	X		X	X	X
Xestoleberis opina					X	
Xestoleberis seminulata		X				X

reticulata, Pectocythere hughesi, Haplocytheridea sp. A and Opimocythere aff. O. hazeli. Antibythocypris johnsoni and Cytheropteron sp.A are Cretaceous species that are restricted to the very uppermost partof the Prairie Bluff. Eucytherura reticulata and Pectocythere hughesi, which were originally described from the Tertiary, were found in the very uppermost Cretaceous and the lowermost Tertiary. Haplocytheridea sp. A and Opimocythere aff. O. hazeli also appeared and disappeared in a short stratigraphic interval that includes the boundary. Thus, the upper part of Veenia parallelopora Zone can be characterized by the presence of these species together with Veenia parallelopora, Brachycythere foraminosa s.l, Brachycythere ovata (transitional form), and relatively high diversity. On the other hand, the earliest Tertiary interval can be characterized by a sharp drop in the abundance of Cretaceous species and the continuous presence of Haplocytheridea sp. A, Opimocythere aff. O. hazeli, Pectocythere hughesi, and Brachycythere ovata (transitional form) together with the first appearance of incoming species such as Cytherelloidea truncata lowndesensis and Opimocythere hazeli. The K-T boundary at Braggs is placed at the top of the Prairie Bluff, which coincides with the disappearance of many Upper Cretaceous ostracodes.

The K-T boundary interval at Shell Creek and Lynn Creek is different in that a sand is present at the base of the Clayton Formation. This sand contains pseudomorphs of impact spherules. Even though there are questions about the actual origin of the sand, and because of preservation, on the indigenous nature of the Upper Cretaceous ostracode specimens in the sand, the content of the sand reveals valuable information. The presence of the microspherule pseudomorphs in the lower part of the sand correlates it with the boundary clay at El Kef and therefore, establishes the K-T boundary in the Gulf Coast. One important question that need to be answered is why the sand is unusually missing at the Braggs section which otherwise is the stratigraphically most complete. Mancini and others (1989) suggested that a difference in the paleotopography of the Prairie Bluff depositional surface may account for the absence of the sand (see also Smit and others, 1994). It is probable that there was a topographic low or depression of some sort at Shell Creek and Lynn Creek.

Based on the ostracode criteria developed at Braggs, the magnitude of the disconformity at Shell Creek and Lynn Creek is greater. The species that characterize the uppermost part of the Veenia parallelopora Zone are absent at Shell Creek and Lynn Creek. This is consistent with the calcareous nannofossil interpretation in that the Micula prinsii was found only at Braggs. However, the presence of the incoming species of Eucytherura, Eucytherura aff. E. reticulata at Shell Creek suggests that the top of the Prairie Bluff here is slightly younger than at Lynn Creek. Conversely, the Clayton sand, containing pseudomorphs of impact microspherules in the lower part is present at Shell Creek and Lynn Creek but not at Braggs. The K-T boundary at Shell Creek and Lynn Creek, therefore, is placed at the base of the sand.

The presence of poorly preserved specimens of "Cretaceous" species in the Clayton sand and the absence of incoming forms suggests that the sand assemblage may be reworked from the Prairie Bluff. However, the sand assemblage at least at Lynn Creek, is not closely similar to that of the immediately underlying Prairie Bluff but is compositionally more akin to that found in the Owl Creek sand and the less calcareous Prairie Bluff to the north. Characteristic incoming species were found in the marl above the basal sand at Lynn Creek. Table 18 lists Upper Cretaceous specimens found in the lowermost Tertiary at Braggs, Shell Creek, Lynn Creek, and at the Texas samples reported by Maddocks (1985) and reexamined during the couse of this study. Some "Cretaceous" ostracode species are found consistently above the K-T boundary in all sections suggesting that they are survivors. These include Antibythocypris crassa, Antibythocypris minuta, Bairdoppilata magna, Brachycythere foraminosa s.l., Brachycythere ovata (transitional form), Brachycythere rhomboidalis and Curfsina

Table 18 A list of Upper Cretaceous ostracodes found in the basal Tertiary unit of this study in comparison with those in the sections of east Texas.

	East Texas			This study		
Upper Cretaceous species	Littig Quarry	Walkers Creek	Brazos River	Shell Creek	Lynn Creek	Braggs roadcut
Amphicytherura curta				X		X
Ascetoleberis hazardi			X			
Antibythocypris crassa				X	X	X
Antibythocypris fabaformis				X		
Antibythocypris gooberi					X	X
Antibythocypris macropora	X		X			
Antibythocypris minuta				X	X	X
Antibythocypris multilira					X	
Antibythocypris pataulensis				X	X	
Antibythocypris phaseolite					X	
Anticythereis sp.15				X		
Anticythereis copelandi				X		
Bairdoppilata magna				X	X	X
Brachycythere foraminosa s.l.				X	X	X
Brachycythere ledaforma		X		X		
Brachycythere ovata			X	X	X	X
Brachycythere rhomboidalis		X	X	X	X	X
Curfsina communis			X	X	X	X
Cytherelloidea aff. C. austinensis				X		
Cytherelloidea bicosta				X		
Cytherelloidea spiralia				X		
Cytheropteron castorensis			X			X
Cytheropteron navarroense			X			
Escharacytheridea micropunc		X				
Escharacytheridea pinochii						X
Haplocytheridea bruceclarki		X		X		X
Haplocytheridea everetti				X	X	
Haplocytheridea renfroensis		X	X			
Limburgina foresterae					X	X
Loxoconcha clinocosta	X					X
Orthonotacythere hannai				X		
"Planileberis" cf. "P." costatana				X		X
Pterygocythere saratogana			X			
Platycosta lixula			X	X		
Veenia arachoides					X	
Veenia parallelopora				X	X	
Xestoleberis opina				X		X
Xestoleberis seminulata				X	X	

communis. At Braggs, the "Cretaceous" specimens are as well preserved as those that are clearly Tertiary and include both robust and delicate forms. The delicate species include Loxoconcha clinocosta and Cytheropteron castorensis which do not exhibit any dissolution, corrosion or recrystallization features, and therefore are considered indigenous taxa. This conclusion differs from that made by Smith (1978) who considered all "Cretaceous" specimens found in the Tertiary at Braggs to be reworked.

More uncommon "Cretaceous" species including Antibythocypris fabaformis, Antibythocypris multilira, Antibythocypris pataulensis, Antibythocypris phaseolites, Anticythereis sp. 15, Anticythereis copelandi, Cytherelloidea aff. C. austinensis, Cytherelloidea spiralia, Orthonotacythere hannai, Veenia arachoides and Veenia parallelopora that were found inconsistently in these sections may or may not be redeposited, and are in need of further study.

The common presence of reworked Upper Cretaceous specimens of ostracodes in the basal Clayton sand suggests that the sand was redeposited either during the sealevel lowstand or perhaps by an impact-generated storm wave. After the deposition of the unusual sand unit, the Tertiary strata deposited in a normal shallow marine environment. The dominance of Cytherella in the Clayton marl at Lynn Creek and the dominance of the representatives of the Cytherideidae at Braggs suggests that the calcareous Clayton units of northeast Mississippi were deposited in a relatively deeper water offshore environment and the units of central Alabama in a more nearshore environment. The presence of thermophillic genus Cytherelloidea in the Clayton just above the boundary (sample B15) at Braggs also suggests that the marine climate at the onset of the Tertiary in this area was warm temperate or warmer.

REFERENCES TO CHAPTER V

Alvarez, L. W., Alvarez, W., Asaro, F. and Michel, H. V., 1980, Extraterrestrial cause for the Cretaceous-Tertiary extinction: Science, 208, 1095-1108.

Berggren, W. A. and Miller, K. G., 1988, Paleogene tropical planktonic foraminiferal biostratigraphy and magnetobiochronology: Micropaleontology, 34, 362-380.

Copeland, C. W., 1968, Facies changes in the Selma Group in central and eastern Alabama: *in* Scott, J. C., Chm., eds., Facies changes in the Selma Group in central and eastern Alabama: Alabama Geological Society Guidebook 6th Field Trip, 2-26.

Copeland, C. W. and Mancini, E. A., 1986, Cretaceous-Tertiary boundary southeast of Braggs, Lowndes County, Alabama: *in* Neathery, T. L., eds., Southeastern Section of the Geological Society of America, Centennial Field Guide, 369-372.

Cowie, J. W., Ziegler, W. and Remaine, J., 1989, Stratigraphic Commission accelerates progress, 1984 to 1989: Episodes, 112, 79-83.

Donovan, A. D., Baum, G. R., Blechschmidt, G. L., Loutit, T. S., Pflum, C. E. and Vail, P. R., 1988, Sequence stratigraphic setting of the Cretaceous-Tertiary boundary in Central Alabama: *in* Wilgus, C. K. and others, eds., Sea-level changes-an integrated approach, Society of Economic Paleontologists and Mineralogists Special Publication 42, 299-307.

Gibson, T. G. and Buzas, M. A., 1973, Species diversity: patterns in modern and Miocene foraminifera of the eastern margin of North America: GSA Bulletin, 84, 217-238.

Habib, D., 1994, Biostratigraphic evidence of the KT boundary in the eastern Gulf Coastal Plain, north of the Chicxulub crator: New developments regarding the K/T event and other catastrophes in earth history, Houston, Texas, Lunar and Planetary Institute, 45-46

Habib, D., Moshkovitz, S. and Kramer, C., 1992, Dinoflagellate and calcareous nannofossil response to sea-level change in Cretaceous-Tertiary boundary sections: Geology, 20(2), 165-168.

Hildebrand, A. R., Penfield, G. T., Kring, D. A., Pilkington, M., Camargo Z., A., Jacobsen, S. B. and Boynton, W. V., 1991, Chicxulub crater: A possible Cretaceous/Tertiary boundary impact crater on the Yucatán Peninsula, Mexico: Geology, 19, 867-871.

Jones, D. S., Mueller, P. A., Bryan, J. R., Dobson, J. P., Channel, J. E. T., Zachos, J. C. and Arthur, M. A., 1987, Biotic, geochemical and paleomagnetic changes across the Cretaceous/Tertiary boundary at Braggs, Alabama: Geology, 15, 311-315.

Keller, G., 1988, Extinction, survivorship and evolution of planktonic foraminifers across the Cretaceous/Tertiary boundary at El Kef, Tunisia: Marine Micropaleontology, 13, 239-263.

Keller, G., 1989, Extended Cretaceous/Tertiary boundary extinctions and delayed population change in planktonic foraminifera from Brazos River, Texas: Paleoceanography, 4, 287-332.

LaMoreaux, P. E. and Toulmin, L. D., 1959, Geology and groundwater resources of Wilcox County, Alabama: Alabama Geological Survey County Report, 4, 280p.

Liu, C. and Olsson, R. K., 1992, Evolutionary radiation of microperforate planktonic foraminifera following the K/T mass extinction event: Journal of Foraminiferal Research, 22, 328-346.

MacArthur, R. H. and MacArthur, J. W., 1961, On bird species diversity: Ecology, 42, 594-598.

Maddocks, R. F., 1985, Ostracoda of Cretaceous-Tertiary contact sections in Central Texas: Gulf Coast Association of Geological Societies Transactions, 35, 445-456.

Mancini, E. A. and Tew, B. H., 1989, Tertiary field trip: Copeland, Charles W., Mancini, Ernest A., Rindsberg, Andrew K., Smith, Charles C., Tew, Berry H. Upper Cretaceous and Tertiary lithostratigraphy and biostratigraphy of west central Alabama. Geol. Surv. Ala., Tuscaloosa, Al, United States. Alabama Geological Society, Annual Field Trip Guidebook, 26, 47-74.

Mancini, E. A., Tew, B. H. and Smith, C. C., 1989, Cretaceous-Tertiary contact, Mississippi and Alabama: Journal of Foraminiferal Research, 19(2), 93-104.

Monroe, W. H., 1941, Notes on deposits of Selma and Ripley age in Alabama: Alabama Geological Survey Bulletin, 48, 150 p.

Moshkovitz, S. and Habib, D., 1993, Calcareous nannofossil and dinoflagellate stratigraphy of the Cretaceous-Tertiary boundary, Alabama and Georgia: micropaleontology, 39(2), 167-191.

Olsson, R. K. and Liu, C., 1994, On the reality of the KT boundary: New developments regarding the K/T event and other catastrophes in earth history, Houston, Texas, Lunar and Planetary Institute, 87-88

Olsson, R. K. and Lui, C., 1993, Controversies on the Placement of Cretaceous-Paleogene Boundary and the K/P Mass Extinction of Planktonic Foraminifera: Palaios, 8, 127-139.

Pielou, E. C., 1966, The measurement of diversity in different types of biological collections: Journal of Theoretical Biology, 13, 131-144.

Pitakpaivan, K., Byerly, G. R. and Hazel, J. E., 1994, Pseudomorphs of impact spherules from a Cretaceous-Tertiary boundary section at Shell Creek, Alabama: Earth and Planetary Science Letters, 124(1-4), 49-56.

Pitakpaivan, K. and Hazel, J. E., 1992, Pseudomorphs of Microtektites at the Cretaceous/Tertiary Boundary in Alabama and Mississippi: Geological Society of America Abstracts with Programs, 24(7), A361.

Pitakpaivan, K. and Hazel, J. E., 1994, Ostracodes and Chronostratigraphic position of the Upper Cretaceous Arkadelphia Formation of Arkansas: Journal of Paleontology, 68(1), 111-122.

Russell, E. E., Keady, D. M., Mancini, E. E. and Smith, C. C., Ed., 1983, Upper Cretaceous Lithostratigraphy and Biostratigraphy in Northeast Mississippi, Southwest Alabama, and Northwest Alabama, Shelf Chalks and Clastics: Field Trip Guidebook for 1983 Spring Field Trip of Gulf Coast Section: Society of Economic Paleontologists and Mineralogists.

Savrda, C. E., 1993, Ichnosedimentologic evidence for a noncatastrophic origin of Cretaceous-Tertiary boundary sands in Alabama: Geology, 21, 1075-1078.

Smit, J., 1982, Extinction and evolution of planktonic foraminifera after a major impact at the Cretaceous/Tertiary boundary: Geological Society of America Special Paper, 190, 329-352.

Smit, J., Montanari, A., et al., 1992, Tektite-bearing, deep-water clastic unit at the Cretaceous-Tertiary boundary in northeastern Mexico: Geology, 20, 99-103.

Smit, J., Roep, T. B., Alvarez, W., Claeys, P., Montanari, S. and Grajales, M., 1994, Impact-tsunami-generated clastic beds at the KT boundary of the gulf Coastal Plain: a synthesis of old and new outcrops: New developments regarding the K/T event and other catastrophes in earth history, Houston, Texas, Lunar and Planetary Institute, 117-119

Smit, J. and Romein, A. J. T., 1985, A sequence of events across the Cretaceous-Tertiary boundary: Earth and Planetary Science Letters, 74, 155-170.

Thierstein, H. R., 1981, Late Cretaceous nannoplankton and the change at Cretaceous-Tertiary boundary: Society of Economic Paleontologists and Mineralogists Special Publication, (32), 355–394.

Worsley, T., 1974, The Cretaceous-Tertiary boundary event in the ocean: *in* W. W. Hay, ed., Studies in paleoceanography, Society of Economic Paleontologists and Mineralogists Special Publication 20, 94-125.

CHAPTER VI

CONCLUSIONS

The first study presented here provides a biostratigraphic framework for the uppermost Cretaceous (late Maastrichtian) units of the Gulf Coastal Plain. The ostracode assemblage of the Arkadelphia Formation, upper Maastrichtian, of southwestern Arkansas suggests that the youngest but longest Cretaceous ostracode zone, the Platycosta lixula Zone of the Gulf Coastal Province can be divided. A new ostracode interval zone, the Veenia parallelopora Zone, is proposed. Comparisons with planktonic microfossil zonations suggest that it is restricted to the late Maastrichtian and thus is a valuable tool for correlation of sublittoral Gulf Coastal Plain units in which diagnostic planktonic forms are often rare or absent. The most useful species besides the nominate taxon is Brachycythere foraminosa.

The study of major distributional patterns of ostracodes from correlative uppermost Cretaceous units within the molluscan Haustator bilira Assemblage Zone strengthens the applicability of the Veenia parallelopora Zone, and provides an ostracode biofacies model that can be used for paleoenvironmental interpretation. The main conclusions of this part of the study are:

1) The zone-indicator species, Veenia parallelopora and the principal characterizing form, Brachycythere foraminosa, are geographically widely distributed.The former is most common in offshore carbonate and calcareous-argillaceous facies. Brachycythere foraminosa, on the other hand, is common in both clastic-dominated units and carbonate-dominated units, and therefore, is a very useful species for recognizing the chronozone.

2) Veenia parallelopora is less abundant than Brachycythere foraminosa and may not be recovered if sample sizes are too small. In addition to Brachycythere foraminosa, Veenia adkinsi and Anticythereis copelandi are chronostratigraphically diagnostic species.

3) The extinction of Fissocarinocythere pidgeoni is at about the same time as the first evolutionary appearance of Veenia parallelopora. The absence of Fissocarinocythere pidgeoni is negative, but important indicator of the chronozone of the Veenia parallelopora Zone.

4) Five ostracode biofacies were recognized within the eastern Gulf Coastal Plain. Biofacies 1 can be recognized by the following diagnostic species Brachycythere rhomboidalis (ridge form), Loxoconcha minardi, Fissocarinocythere pidgeoni and Anticythereis sp. 8. Biofacies 2 can be recognized by the following diagnostic species Orthonotacythere hannai, Haplocytheridea renfroensis and Loxoconcha cretacea. Biofacies 3 can be recognized by the following diagnostic species Loxoconcha erecticosta, Cytheromorpha cf. C. arbenzi, Haplocytheridea globosa, Platycosta lixula, Antibythocypris multilira, Antibythocypris phaseolites, Loxoconcha striata and Aversovalva fossata. Biofacies 4 can be recognized by the following diagnostic species Anticythereis sp. 10, Veenia arachoides, Cytherelloidea crafti, Escharacytheridea pinochii, Bairdoppilata magna, Limburgina foresterae, Anticythereis sp. 4, Anticythereis sp. 17, Antibythocypris minuta, and Anticythereis sp. 14. Biofacies 5 can be recognized by the following diagnostic species Ascetoleberis hazardi, Brachycythere ledaforma, Cytheropteron navarroense, Krithe whitecliffsensis, Alatacythere aff. A. serrata, Escharacytheridea micropunctata, Cytherella spp., Pterygocythere saratogana, Cytherelloidea bicosta s.l., Cytheropteron coryelli, Veenia parallelopora, Veenia adkinsi, and Eucythere sohli.

5) Most of the ostracode species in particular genera exhibit similar patterns of facies distribution. A common form that is an exception to this rule is Haplocytheridea. Most species of this genus are found in inner shelf clastic facies, but a few are also found in further offshore carbonate facies. Terrigeneous shelf and prodelta deposits are

characterized by species of Amphicytherura, Antibythocypris, Anticythereis, Aversovalva, Cytheromorpha, and Loxoconcha, together with Brachycythere rhomboidalis, Escharacytheridea magnamandibulata, Haplocytheridea everetti, Haplocytheridea renfroensis, Xestoleberis opina, and Xestoleberis seminulata. More offshore shelf carbonate deposits are characterized by species of Alatacythere, Ascetoleberis, Bairdoppilata, Bythoceratina, Cuneoceratina, Cytherella, Cytherelloidea, Eucythere, Krithe, "Monoceratina", "Planileberis", Pterygocythere, Sphaeroleberis, and Veenia, together with Brachycythere ledaforma, Cytheropteron coryelli, Cytheropteron navarroense, and Haplocytheridea bruceclarki.

The study of the Cretaceous-Tertiary boundary sections at Braggs, Shell Creek and Lynn Creek provides the first detailed documentation of ostracode distributional patterns across the boundary. The main conclusions are:

1) Ostracodes show no pattern of gradual extinction across the K-T boundary interval at these localities. In fact, they were found in high abundance with high species diversity during the late Maastrichtian. The elimination of the Cretaceous assemblages is abrupt and synchronous, and correlates well with nannofossil and macrofossil extinctions. Within the Gulf Coastal Plain, geographically widely distributed species exhibit the same extinction pattern.

2) The uppermost Maastrichtian, which is in the uppermost part of the Veenia parallelopora Zone, is characterized by high species diversity and the presence of the following characteristic species: Veenia parallelopora, Brachycythere foraminosa, Brachycythere ovata (transitional form), Antibythocypris johnsoni, Eucythere reticulata, Opimocythere aff. O. hazeli, and Pectocythere hughesi.

3) The lower Danian is characterized by the absence of many species typical of the later Cretaceous, a few "Cretaceous survivor" taxa, and the sequential appearance of

incoming Tertiary species. The taxa believed to be survivors include Bairdoppilata magna, Cytherella spp., Curfsina communis and Loxoconcha clinocosta.

4) The K-T boundary contacts of Braggs, Shell Creek and Lynn Creek sections are disconformable. At Braggs, the K-T boundary is at the contact of the Prairie Bluff and the Clayton Formation. This section has the least incomplete rock record; however, the oldest Tertiary Clayton sand is absent. The Prairie Bluff is of latest Maastrichtian age as indicated by ostracodes and nannofossils. At Shell Creek and Lynn Creek, latest Maastrichtian deposits are missing.

5) The presence of the pseudomorphs of impact microspherules in the lower part of a thin, discontinuous sand at the base of Clayton Formation at Shell Creek and Lynn Creek indicates a correlation of at least the lower part of the sand with the boundary clay at the K-T boundary stratotype section at El Kef, Tunisia. The sand is characterized by the presence of the pseudomorphs, the absence of most Cretaceous taxa, Cretaceous specimens interpreted to be reworked, and no Tertiary incoming species. The reworked Cretaceous assemblage, at least at Lynn Creek, is not similar to that of the immediately underlying Prairie Bluff. This in itself suggests transport.

6) The possible sequence of events is [1] deposition of the Prairie Bluff in a normal marine, relatively offshore, shelf setting, [2] a fall of sea level followed by subaerial exposure and erosion of shelf deposits, [3] fallout of the impact ejecta, [4] deposition of Clayton basal sand in topographic lows and, [5] a rise in sea level with the subsequent return to normal marine, continental shelf deposition.

APPENDIX I

PLATES

Plate 1

1. <u>Antibythocypris</u> <u>elongata</u>, exterior of left valve
2. <u>Antibythocypris</u> <u>multilira</u>, exterior of female left valve
3. <u>Antibythocypris</u> <u>minuta</u>, exterior of female right valve
4. <u>Antibythocypris</u> <u>crassa</u>, exterior of male right valve
5. <u>Antibythocypris</u> <u>trisulcata</u>, exterior of left valve
6. <u>Antibythocypris</u> <u>fabaformis</u>, exterior of male right valve
7. <u>Antibythocypris</u> <u>phaseolites</u>, exterior of female left valve
8. <u>Antibythocypris</u> <u>pataulensis</u>, exterior of female right valve
9. <u>Brachycythere</u> <u>rhomboidalis</u> (ridge form), exterior of left valve

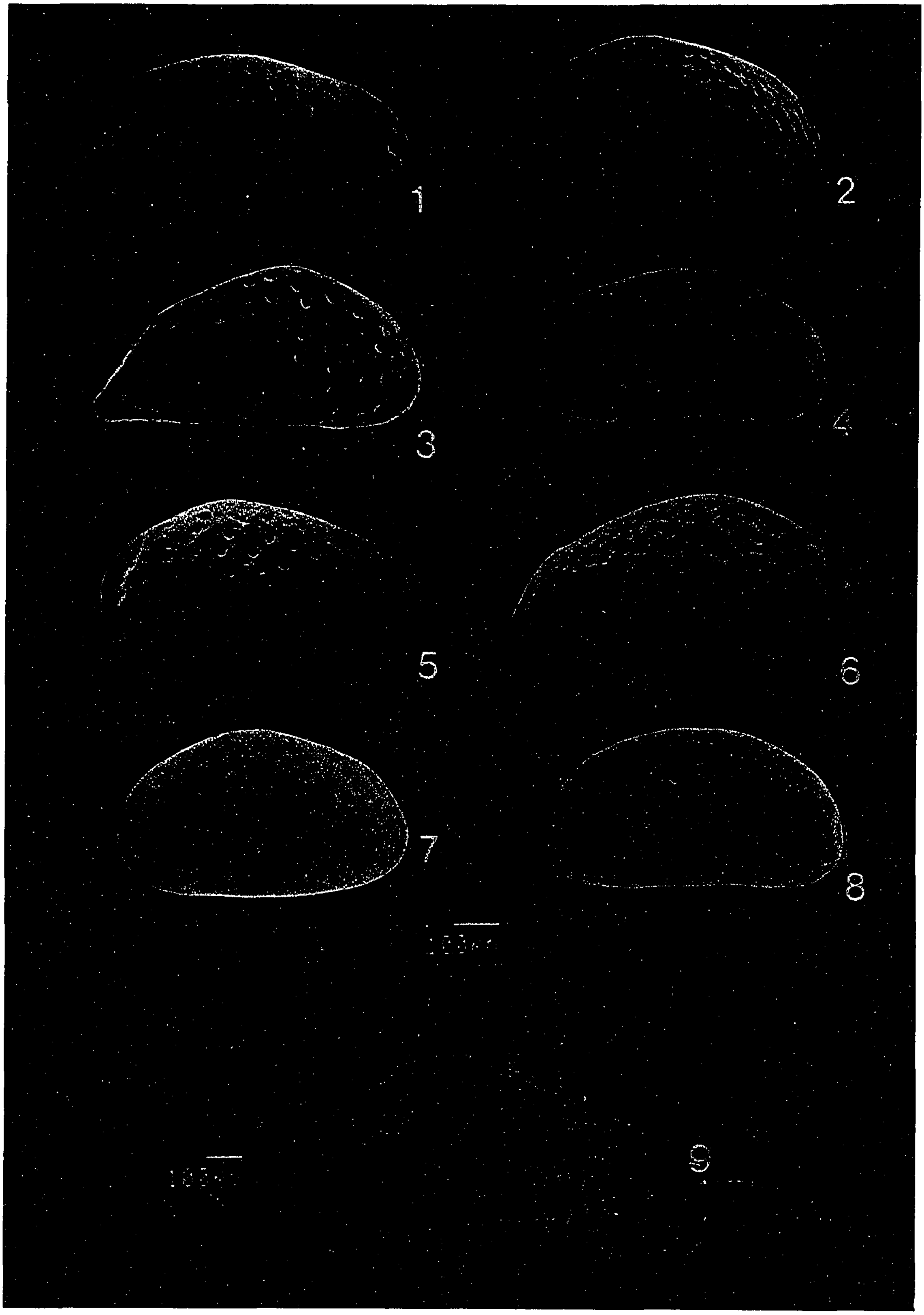


Plate 2

1. Anticythereis sp. 12, exterior of left valve
2. Anticythereis copelandi, exterior of left valve
3. Anticythereis sp. 4, exterior of left valve
4. Anticythereis sp. 4, exterior of right valve
5. Anticythereis sp. 3, exterior of left valve
6. Anticythereis sp. 7, exterior of left valve
7. Anticythereis sp. 11, exterior of female left valve
8. Anticythereis sp. 11, exterior of male right valve
9. Anticythereis sp. 17, exterior of right valve
10. Anticythereis cf. sp. 15, exterior of left valve

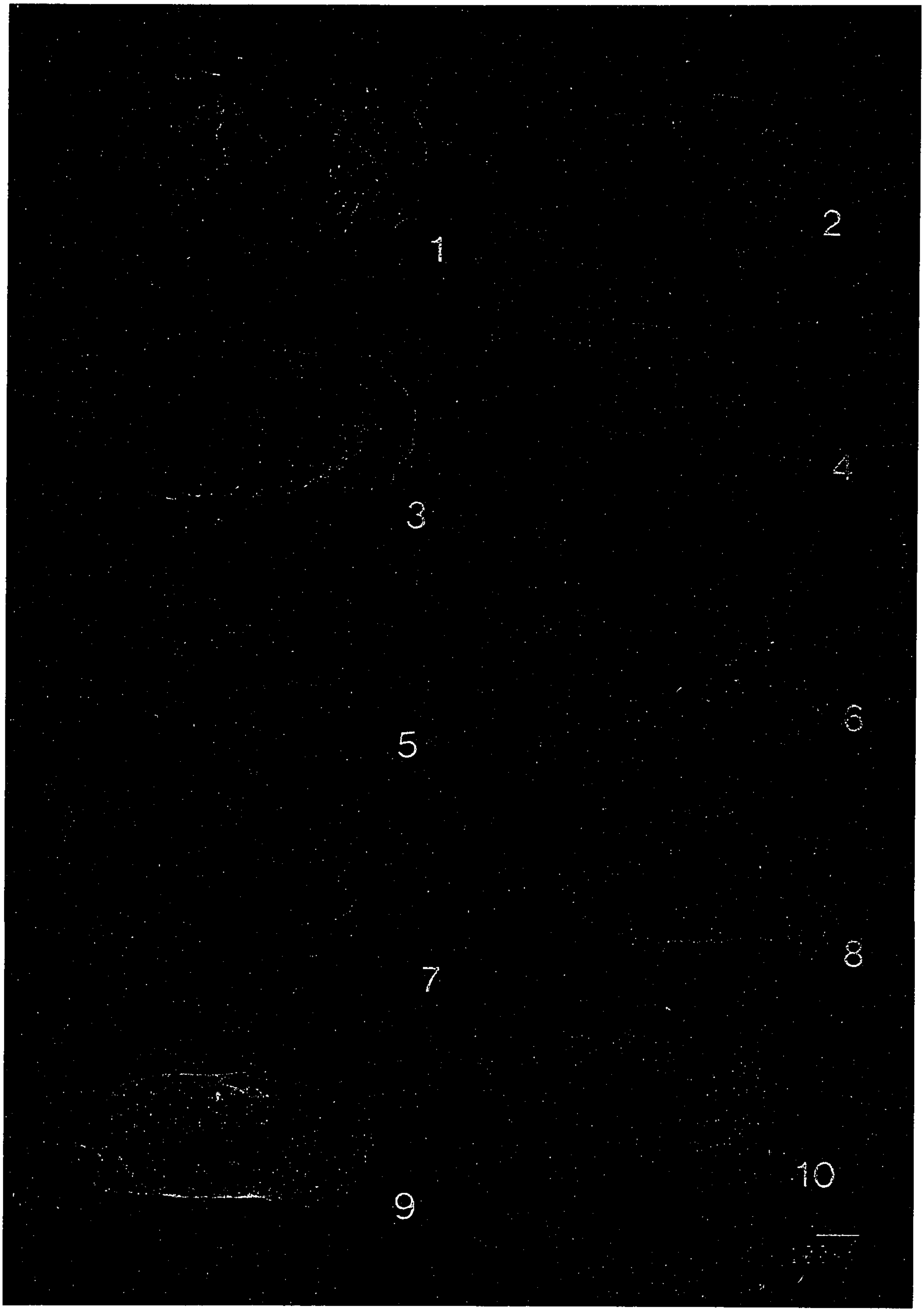

1
2
3
4
5
6
7
8
9
10

Plate 3

1. Anticythereis aff. sp. 8, exterior of female left valve
2. Anticythereis aff. sp. 8, exterior of male right valve
3. Anticythereis sp. 16, exterior of left valve
4. Anticythereis sp. 19, exterior of left valve
5. Anticythereis sp. 1, exterior of right valve
6. Anticythereis sp. 6, exterior of left valve

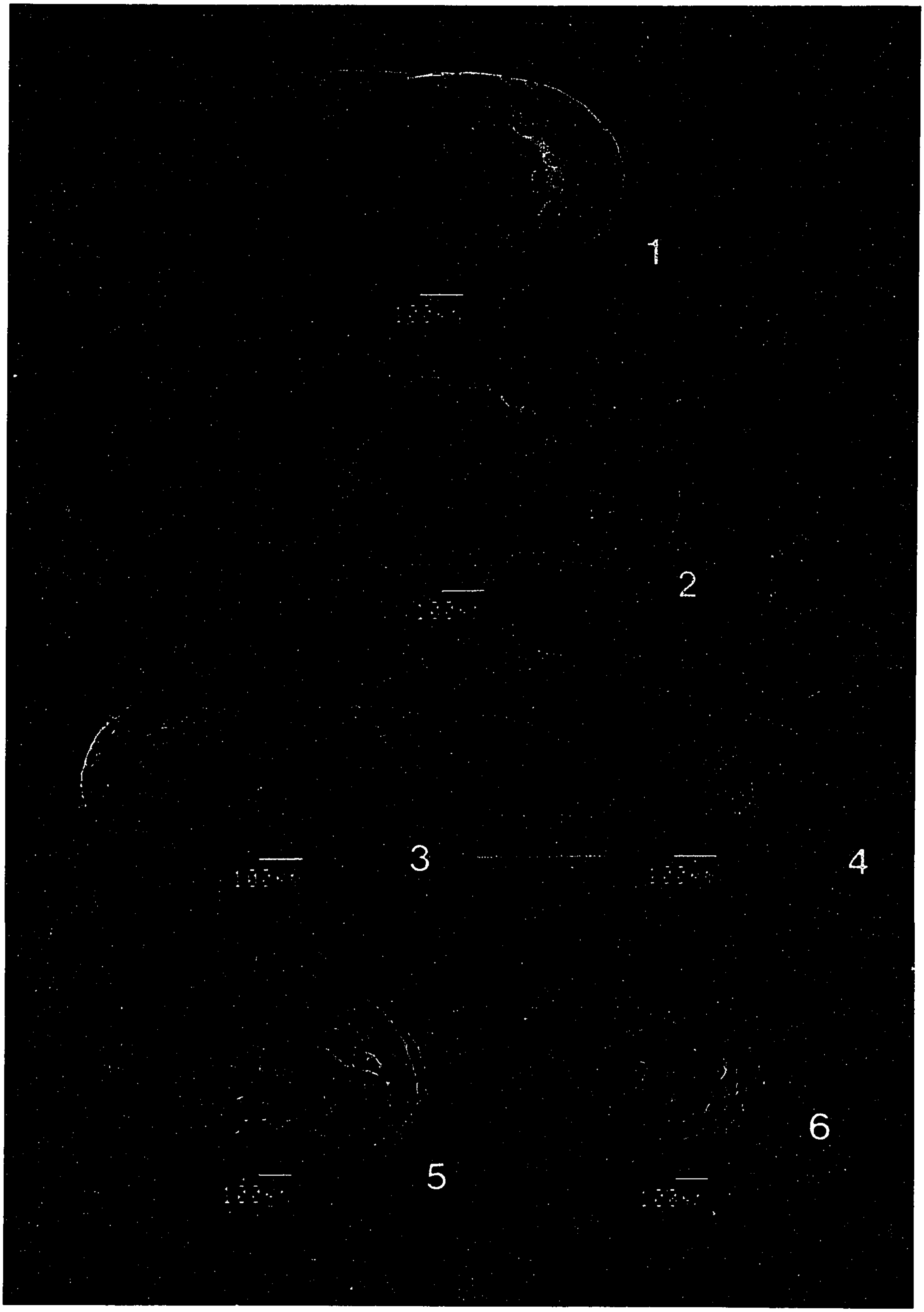

1
2
3
4
5
6

Plate 4

1. Cytherelloidea inflata, exterior of right valve
2. Cytherelloidea austinensis, exterior of right valve
3. Cytherelloidea bicosta, exterior of left valve
4. Cytherelloidea bicosta, exterior of right valve
5. Cytherelloidea crafti, exterior of left valve
6. Cytherelloidea aff. C. spiralia, exterior of left valve
7. Cushmanidea sp. 3, exterior of left valve
8. Cushmanidea sp. 5, exterior of right valve
9. Polylophus asper, exterior of left valve
10. Loxoconcha striata, exterior of left valve

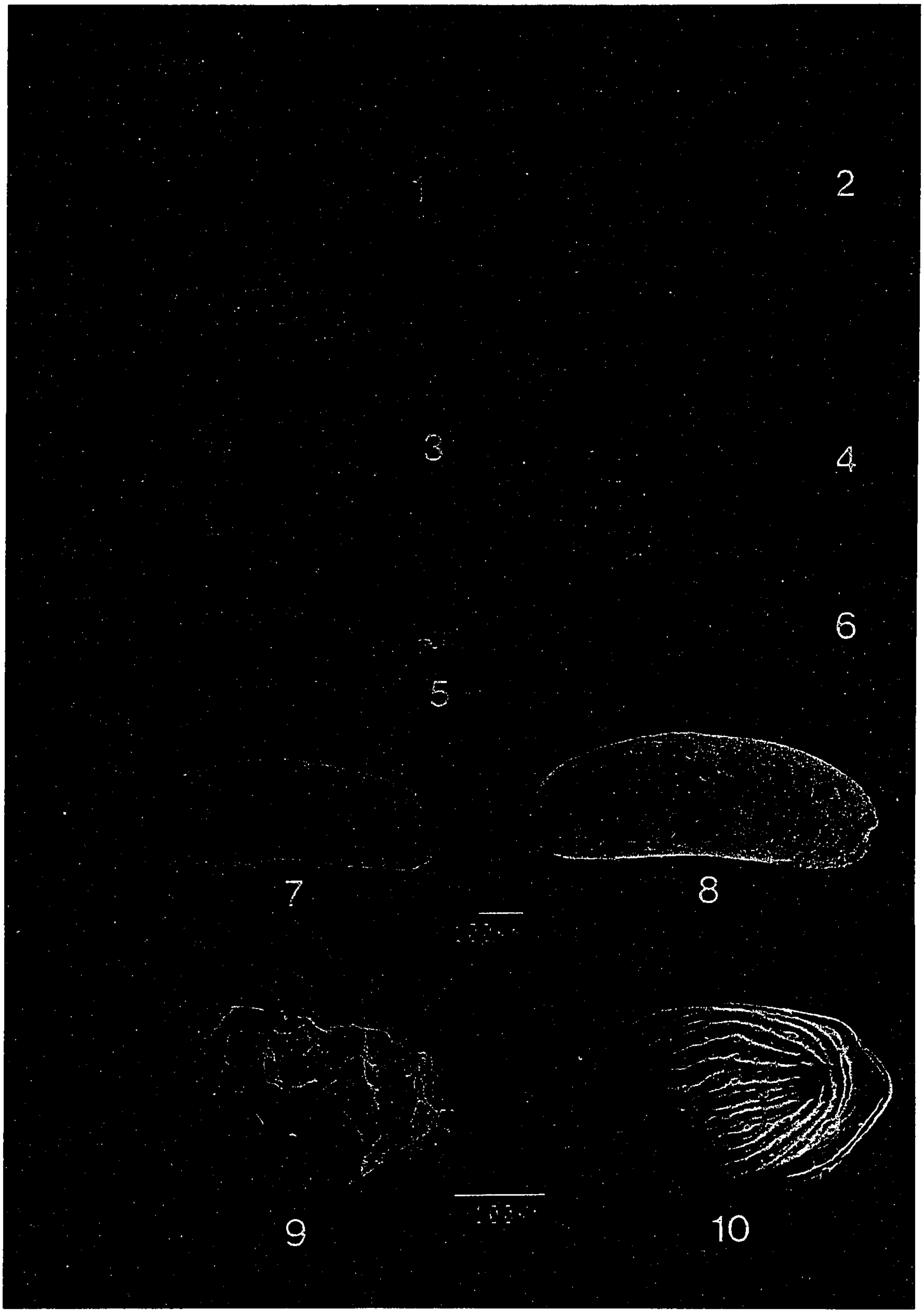

1
2
3
4
5
6
7
8
9
10

Plate 5

1. "Monoceratina" n. sp. C, exterior of left valve
2. Bythoceratina aff. B. umbonata, exterior of left valve
3. Bythoceratina aff. B. acanthoptera, exterior of left valve
4. Cuneoceratina aff. C. pedata, exterior of right valve
5. Cuneoceratina aff. C. prothroensis, exterior of left valve
6. "Cuneoceratina" n. sp. F, exterior of left valve
7. "Monoceratina" n. sp. A, exterior of left valve
8. "Cuneoceratina" n. sp. F, exterior of left valve
9. "Monoceratina" n. sp. D, exterior of left valve
10. "Monoceratina" aff. "M." nitida, exterior of left valve

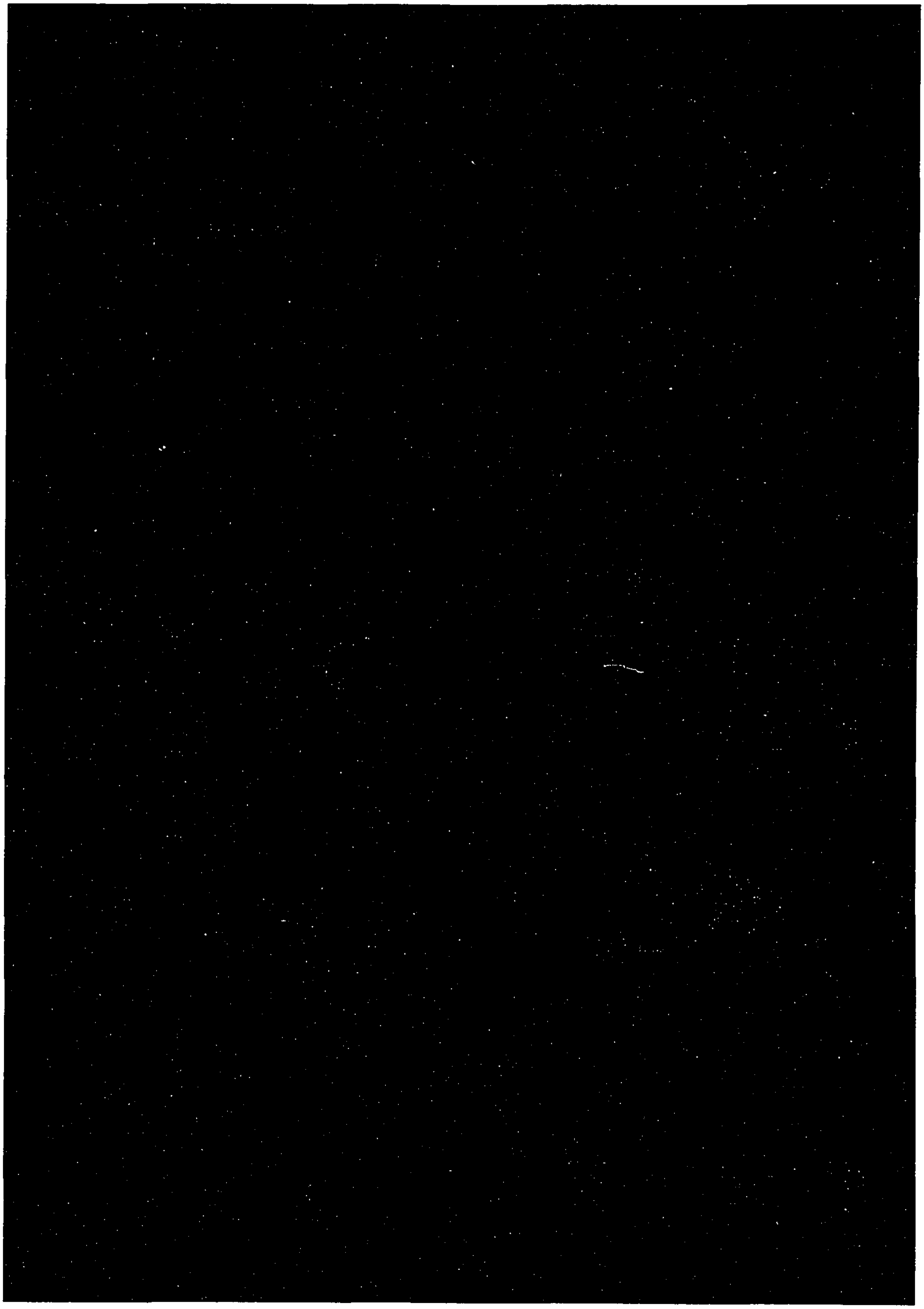


Plate 6

1. Amphicytherura curta, exterior of female left valve
2. Fissocarinocythere pidgeoni, exterior of male right valve
3. Escharacytheridea pinochii, exterior of female left valve
4. Xestoleberis opina, exterior of left valve
5. Soudanella parallelopora, exterior of left valve
6. Brachycythere porosa, exterior of female left valve
7. Brachycythere foraminosa s.l., exterior of female left valve
8. Brachycythere foraminosa s.l., exterior of female left valve
9. Brachycythere foraminosa s.l., exterior of female left valve
10. Brachycythere foraminosa s.l., exterior of female left valve

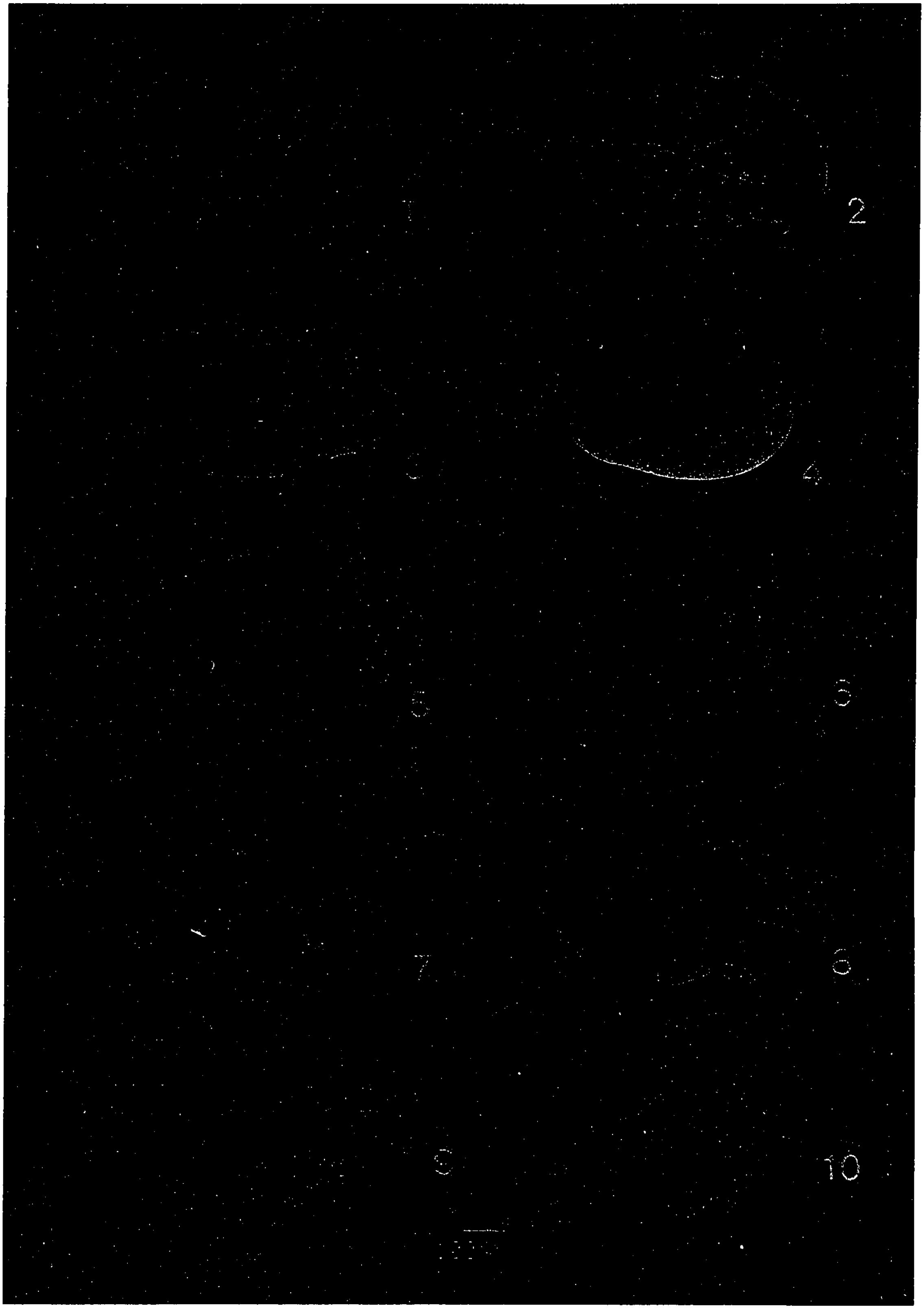

1
2
3
4
5
6
7
8
9
10

Plate 7

1. "Planileberis" cf. "P." costatana, exterior of female left valve

2. "Planileberis" cf. "P." costatana, interior of female right valve

3. "Planileberis" cf. "P." costatana, detail of anterior hinge element in female right valve

4. "Planileberis" cf. "P." costatana, detail of posterior hinge element in female right valve

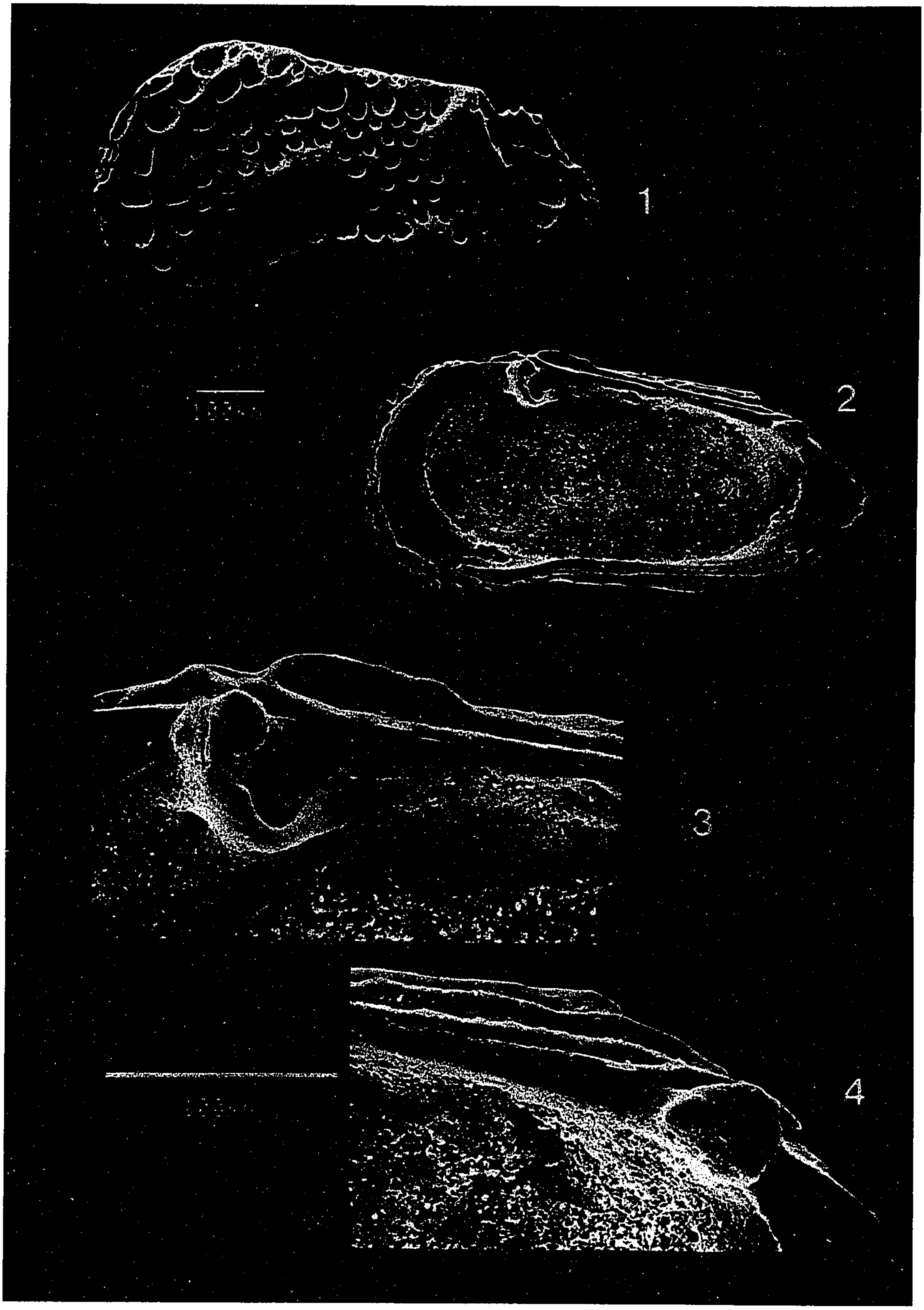

1
2
3
4

Plate 8

1. Limburgina foresterae, exterior of left valve
2. Limburgina foresterae, exterior of right valve
3. Limburgina foresterae, interior of right valve
4. Limburgina foresterae, interior of left valve
5. Limburgina foresterae, detail of muscle scar field in the right valve

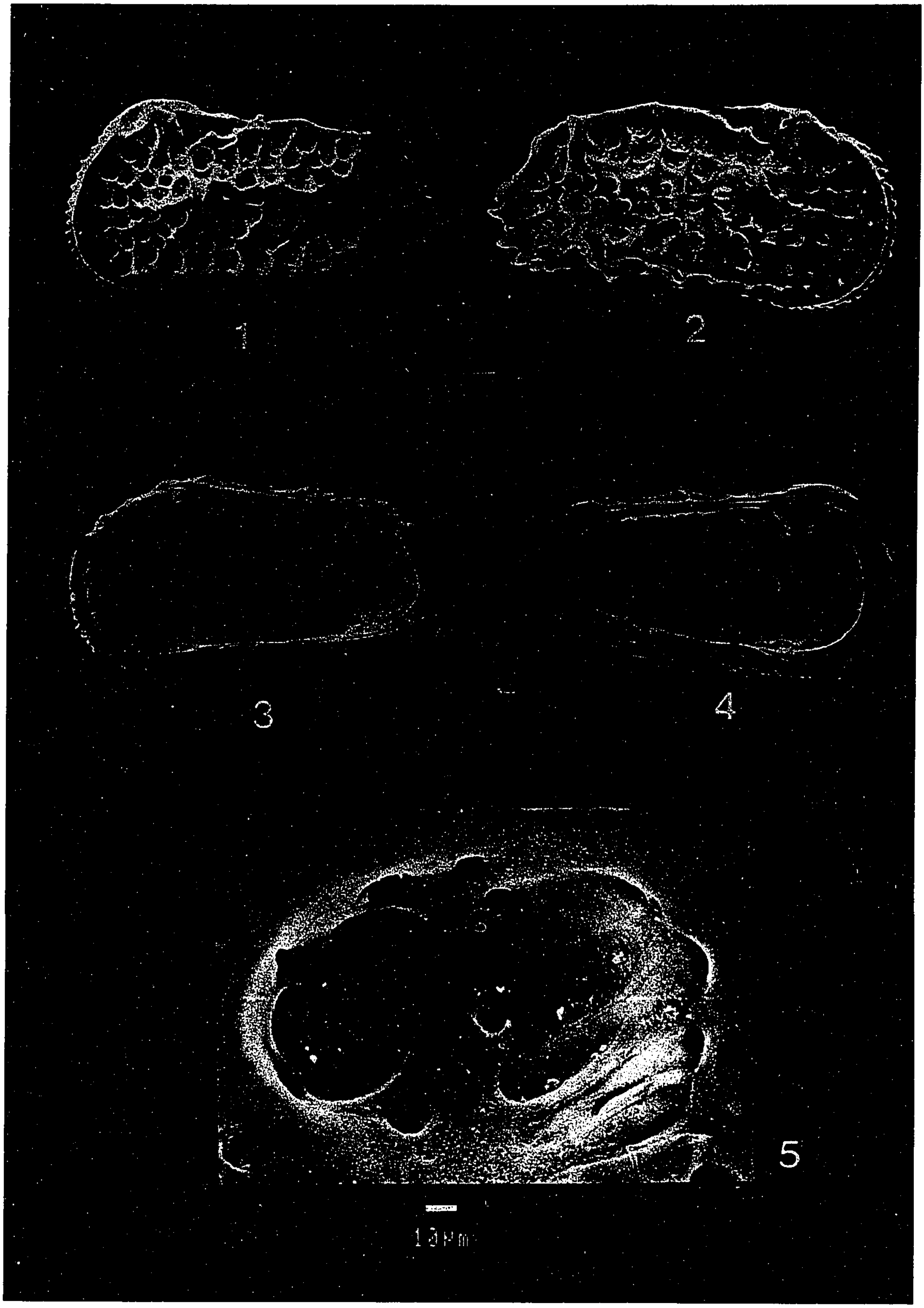

1
2
3
4
5

Plate 9

1. Brachycythere ovata, exterior of female right valve
2. Brachycythere plena, exterior of female right valve
3. Brachycythere ovata (transitional from), exterior of female right valve
4. Opimocythere hazeli, exterior of female left valve
5. Haplocytheridea fornicata, exterior of female left valve
6. Alatacythere lemnicata, exterior of left valve
7. Bairdia suborbiculata, exterior of right valve

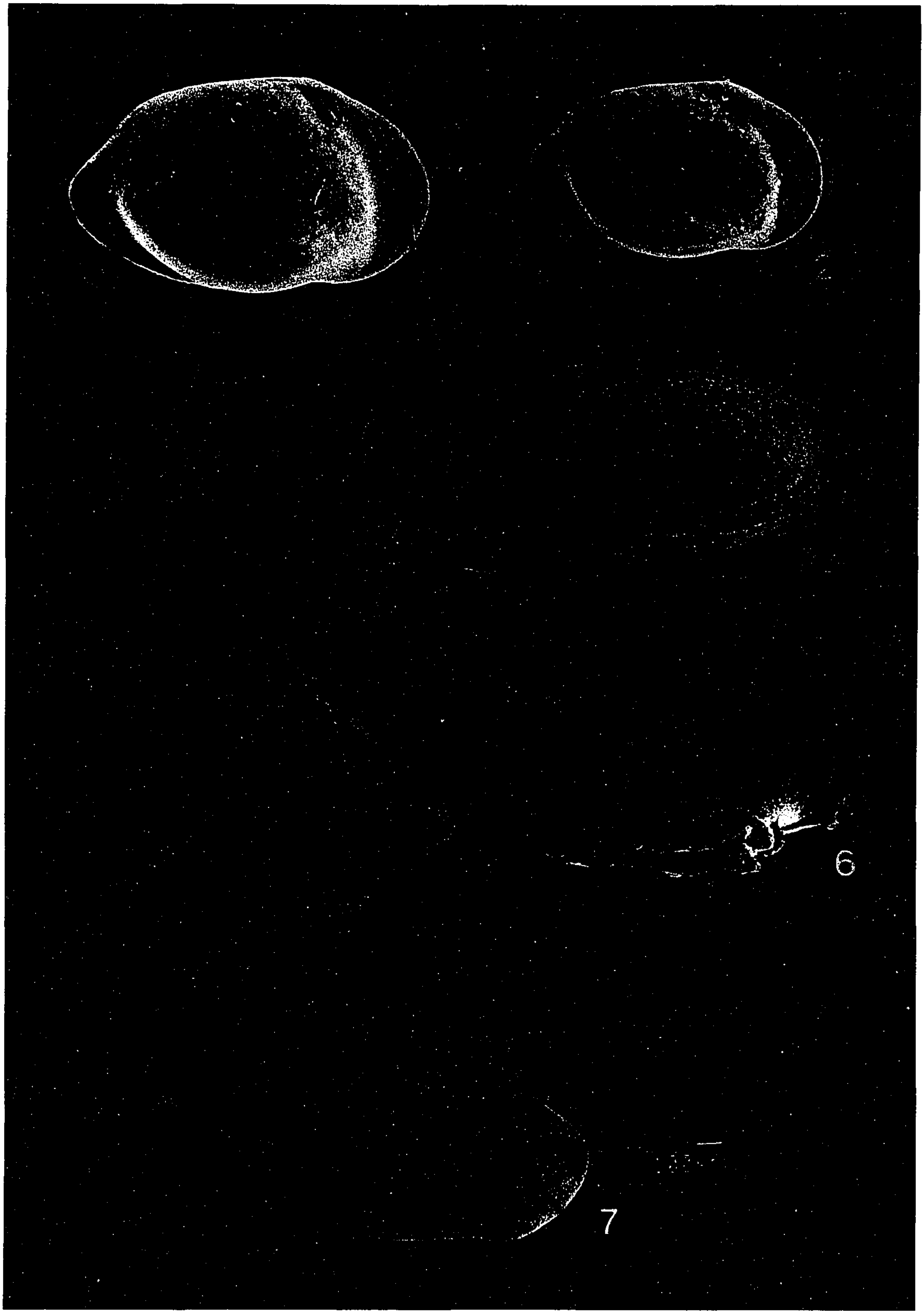

6
7

Plate 10

1. Pectocythere hughesi, exterior of left valve
2. Cytheromorpha braggsensis, exterior of left valve
3. Eucytherura aff. E. reticulata, exterior of female right valve
4. Eucytherura aff. E. reticulata, exterior of male right valve
5. Cytheromorpha pittsi, exterior of left valve
6. Loxoconcha corrugata, exterior of female left valve
7. Hermanites cf. H. plusculmensis, exterior of left valve
8. Hermanites gibsoni, exterior of male left valve

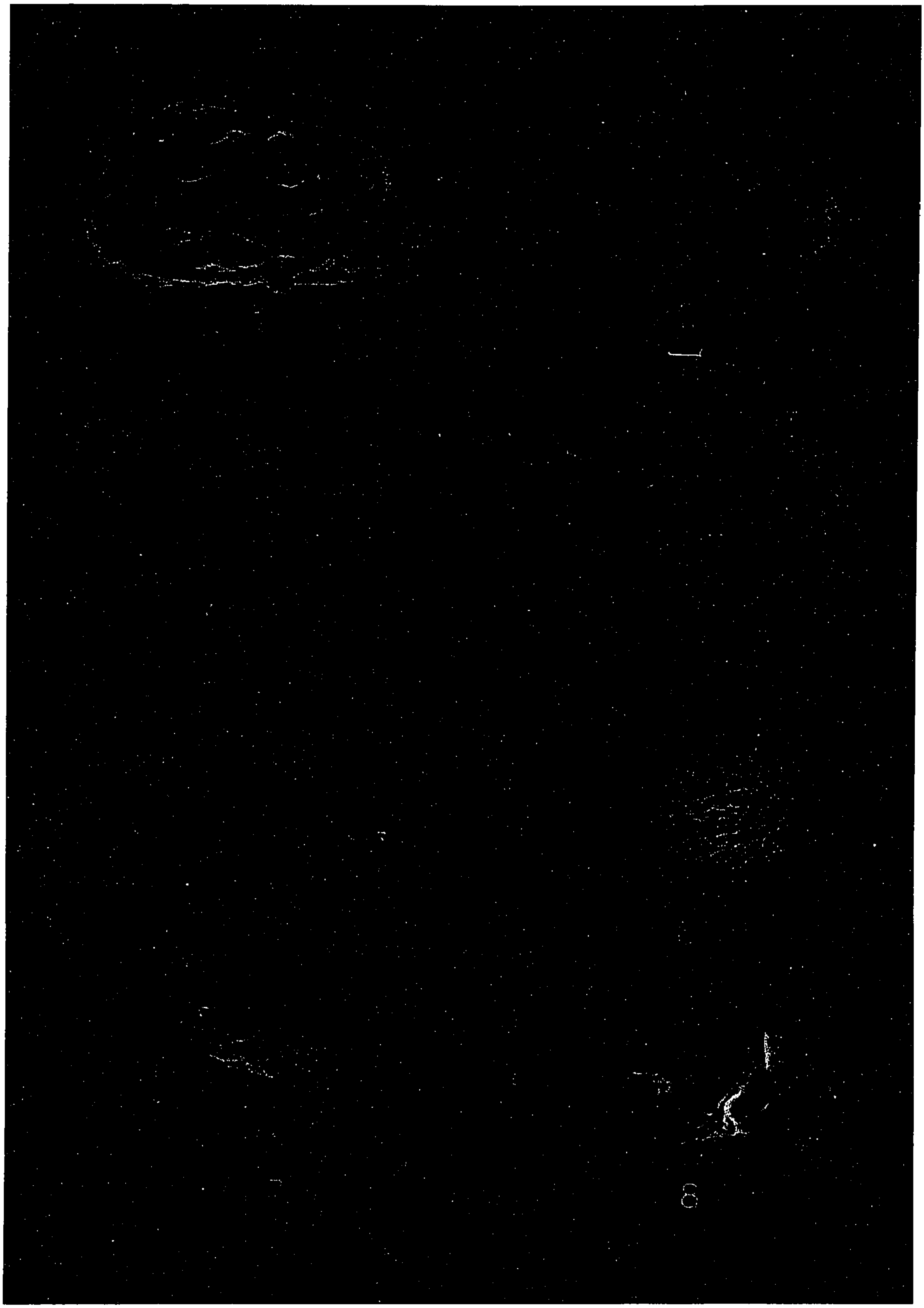
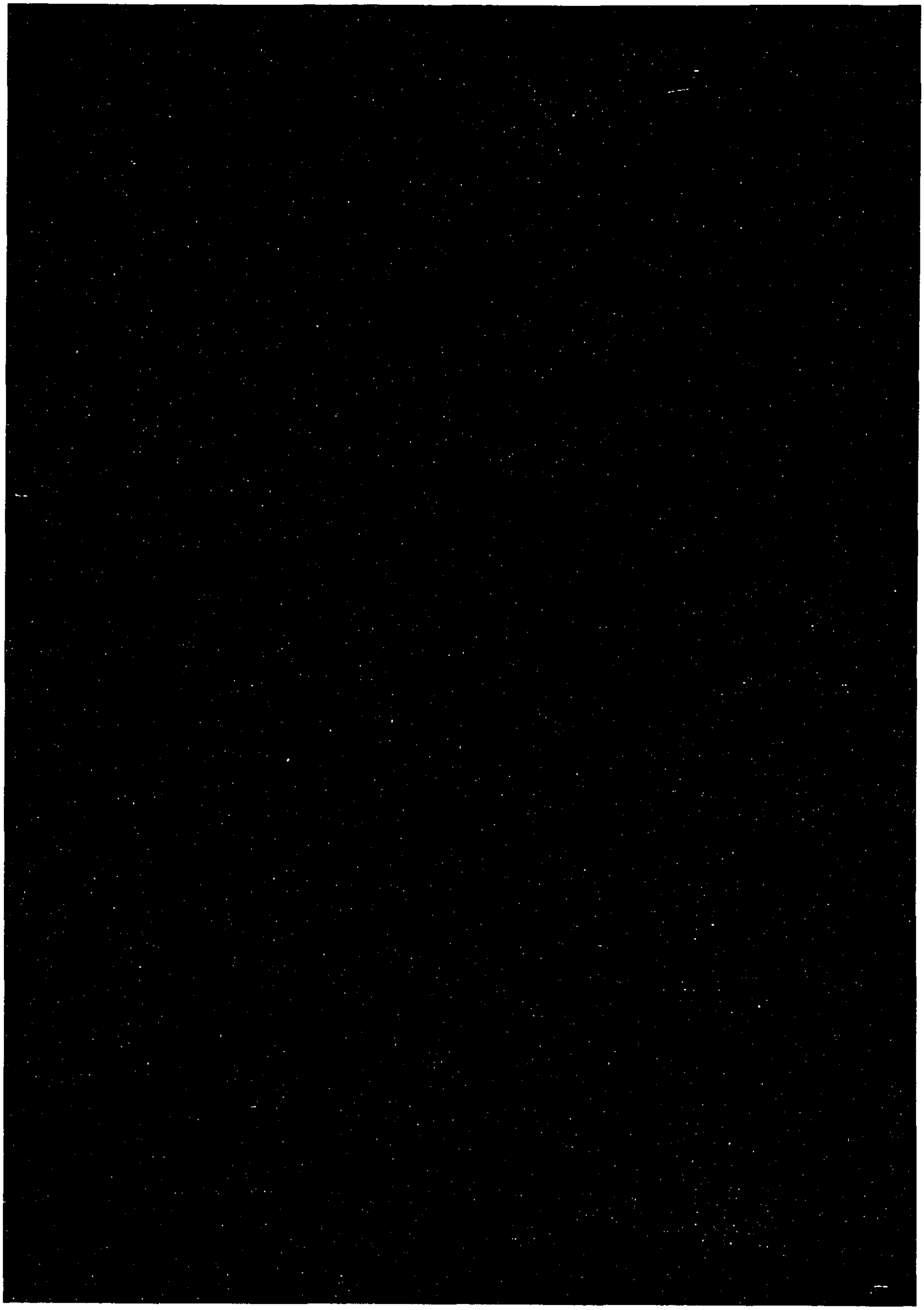


Plate 11

1. Phractocytheridea ruginosa, exterior of female left valve
2. Orthonotacythere cristata, exterior of left valve
3. Cytherelloidea truncata lowndesensis, exterior of right valve
4. Cytherelloidea sullivani, exterior of right valve
5. Hazelina sp. A, exterior of left valve
6. Acanthocythereis washingtonensis, exterior of female left valve
7. Phacorhabdotus sculptilis, exterior of left valve
8. Phacorhabdotus formosa, exterior of right valve
9. Phacorhabdotus aff P. formosa, exterior of left valve
10. Phacorhabdotus aff P. formosa, exterior of right valve



APPENDIX II

SYSTEMATIC PALEONTOLOGY

SYSTEMATIC PALEONTOLOGY

Subclass OSTRACODA Latreille, 1806

Order PODOCOPIDA G.W. Müller, 1894

Suborder PLATYCOPINA Sars, 1866

Family CYTHERELLIDAE Sars, 1866

Genus CYTHERELLA Jones, 1849

CYTHERELLA SPP.

Genus CYTHERELLOIDEA Alexander, 1929

CYTHERELLOIDEA AFF. C. AUSTINENSIS Sexton, 1951

CYTHERELLOIDEA AFF. TOLLETTENSIS Sexton, 1951

CYTHERELLOIDEA AUSTINENSIS Sexton, 1951

Plate 4, figure 2

CYTHERELLOIDEA BICOSTA Crane, 1965

Plate 4, figures 3, 4

CYTHERELLOIDEA CRAFTI Sexton, 1951

Plate 4, figure 5

CYTHERELLOIDEA INFLATA Brown, 1957

Plate 4, figure 1

CYTHERELLOIDEA SPIRALIA Jennings, 1936

Plate 4, figure 6

CYTHERELLOIDEA SULLIVANI Smith, 1978

Plate 11, figure 4

CYTHERELLOIDEA TRUNCATA LOWNDESENSIS Smith, 1978

Plate 11, figure 3

Suborder PODOCOPINA Sars, 1866

Superfamily BAIRDIACEA Sars, 1888

Family BAIRDIIDAE Sars, 1888

Genus BAIRDOPPILATA Coryell, Sample and Jennings, 1935

BAIRDOPPILATA MAGNA (Alexander, 1927)

BAIRDOPPILATA PONDERA Jennings, 1936

Figure 2.4.7

BAIRDOPPILATA SUBORBICULATA (Alexander, 1934)

Plate 9, figure 7

BAIRDIA SP.1

BAIRDIA SP.2

Family BYTHOCYPRIDINAE Maddocks, 1969

Genus BYTHOCYPRIS Brady, 1880

BYTHOCYPRIS WINDHAMI Butler and Jones, 1957

BYTHOCYPRIS SP. 1

BYTHOCYPRIS SP. 2

BYTHOCYPRIS SP. 3

Superfamily CYTHERACEA Baird, 1850

Family CYTHERIDAE Baird, 1850

Subfamily CYTHERINAE Baird, 1850

Tribe CYTHERINI Baird, 1850

Genus CYTHEROMORPHA Hirschmann, 1909

CYTHEROMORPHA BRAGGSENSIS Smith, 1978

Plate 10, figure 2

CYTHEROMORPHA ARBENZI Skinner, 1956

Figure 2.5.6

CYTHEROMORPHA CF. C. PITTSI Smith, 1978

CYTHEROMORPHA PITTSI Smith, 1978

Plate 10, figure 5

Tribe SCHIZOCYTHERINI Mandelstam, 1960

Genus AMPHICYTHERURA Butler & Jones, 1957

AMPHICYTHERURA CURTA (Jennings, 1936)

Plate 6, figure 1

Tribe PECTOCYTHERINI Hanai, 1957

Genus PECTOCYTHERE Hanai, 1957

PECTOCYTHERE HUGHESI Smith, 1978

Plate 10, figure 1

Family EUCYTHERIDAE Puri, 1954

Genus EUCYTHERE Brady, 1868

EUCYTHERE SOHLI Brouwers & Hazel, 1980

Figure 2.6.7

EUCYTHERE N. SP.

Family CYTHERIDEIDAE Sars, 1925

Subfamily CYTHERIDEINAE Sars, 1925

Genus HAPLOCYTHERIDEA Stephenson, 1936

HAPLOCYTHERIDEA BRUCECLARKI (Israelsky, 1929)

Figure 2.7.2

HAPLOCYTHERIDEA EVERETTI (Berry, 1925)

HAPLOCYTHERIDEA FORNICATA (Alexander, 1934)

Plate 9, figure 5

HAPLOCYTHERIDEA GLOBOSA (Alexander, 1929)

HAPLOCYTHERIDEA RENFROENSIS Crane, 1965

Figure 2.7.4

HAPLOCYTHERIDEA N. SP. A

HAPLOCYTHERIDEA N. SP. B

Genus ESCHARACYTHERIDEA Brouwers & Hazel, 1978

ESCHARACYTHERIDEA MAGNAMANDIBULATA Brouwers & Hazel, 1978

Figure 2.6.5

ESCHARACYTHERIDEA MICROPUNCTATA (Alexander, 1929)

Figure 2.6.6

ESCHARACYTHERIDEA PINOCHII (Jennings, 1936)

Plate 6, figure 3

Genus ANTIBYTHOCYPRIS Jennings, 1936

ANTIBYTHOCYPRIS CRASSA Brouwers & Hazel, 1978

Plate 1, figure 4

ANTIBYTHOCYPRIS ELONGATA Brouwers & Hazel, 1978

Plate 1, figure 1

ANTIBYTHOCYPRIS FABAFORMIS (Berry, 1925)

Plate 1, figure 6

ANTIBYTHOCYPRIS GOOBERI Jennings, 1936

Figure 2.4.2

ANTIBYTHOCYPRIS JOHNSONI Smith, 1978

ANTIBYTHOCYPRIS KIDDI Smith, 1978

ANTIBYTHOCYPRIS MACROPORA (Alexander, 1929)

Figure 2.4.3

ANTIBYTHOCYPRIS MINUTA (Berry, 1925)

Plate 1, figure 3

ANTIBYTHOCYPRIS MULTILIRA (Schmidt, 1948)

Plate 1, figure 2

ANTIBYTHOCYPRIS PATAULENSIS (Crane, 1965)

Plate 1, figure 8

ANTIBYTHOCYPRIS PHASEOLITES (Berry, 1925)

Plate 1, figure 7

ANTIBYTHOCYPRIS TRISULCATA Brouwers & Hazel, 1978

Plate 1, figure 5

Genus PHRACTOCYTHERIDEA Sutton & Williams, 1939

PHRACTOCYTHERIDEA RUGINOSA (Alexander, 1934)

Plate 11, figure 1

Family CUSHMANIDEIDAE Puri, 1973

Genus CUSHMANIDEA Blake, 1933

"CUSHMANIDEA" SP.1

"CUSHMANIDEA" SP.2

"CUSHMANIDEA" SP.3

Plate 4, figure 7

"CUSHMANIDEA" SP.4

"CUSHMANIDEA" SP.5

Plate 4, figure 8

Family KRITHIDAE Mandelstam, 1960

Genus KRITHE Brady, Crosskey and Robertson, 1874

KRITHE WHITECLIFFSENSIS Crane, 1965

Figure 2.7.5

KRITHE N. SP. A

Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948

Subfamily TRACHYLEBERIDINAE Sylvester-Bradley, 1948

Tribe TRACHLEBERIDINI Sylvester-Bradley, 1948

Genus FISSOCARINOCYTHERE Brouwers & Hazel, 1978

FISSOCARINOCYTHERE HUNTENSIS (Alexander, 1929)

Figures 2.6.8 and 2.7.1

FISSOCARINOCYTHERE PIDGEONI (Berry, 1925)

Plate 6, figure 2

Genus ACANTHOCYTHEREIS Howe, 1963

ACANTHOCYTHEREIS WASHINGTONENSIS Hazel, 1968

Plate 11, figure 6

Tribe ROCALEBERIDINI Bertels, 1969

Genus ASCETOLEBERIS Brouwers & Hazel, 1978

ASCETOLEBERIS HAZARDI (Israelsky, 1929)

Figures 2.4.5 and 2.4.6

Tribe VEENIINI Puri, 1973

Genus PLANILEBERIS Deroo, 1963

"PLANILEBERIS" CF. "P." COSTATANA (Israelsky, 1929)

Plate 7, figures 1-4

Remarks.— At this time, the placement of this species in the genus "Planileberis" is one of mere convenience. "Planileberis" cf. "P." costatana and related forms probably represent a new genus, but more study is necessary. "Planileberis" is similar in general morphology to the european genus Planileberis, but has a different hinge.

Genus VEENIA Butler & Jones, 1957

VEENIA ADKINSI Smith, 1978

Figure 2.8.3

VEENIA ARACHOIDES (Berry, 1925)

Figure 2.8.4

VEENIA PARALLELOPORA (Alexander, 1929)

Figure 2.8.5

Tribe COSTAINI Hartmann & Puri, 1974

Genus HAZELINA Moos, 1966

HAZELINA SP. A

Plate 11, figure 5

Genus CURFSINA Deroo, 1966

CURFSINA COMMUNIS (Israelsky, 1929)

Figure 2.5.4

Genus PLATYCOSTA Holden, 1964

PLATYCOSTA LIXULA (Crane, 1965)

Figure 2.5.5

Tribe PTERYGOCYTHEREIDINI Puri 1957

Genus ALATACYTHERE Murray & Hussey, 1942

ALATACYTHERE AFF. A. SERRATA (Bonnema, 1940)

Figure 2.4.1

ALATACYTHERE LEMNICATA

Plate 9, figure 6

Genus PTERYGOCYTHERE Hill, 1954

PTERYGOCYTHERE SARATOGANA (Israelsky, 1929)

Figure 2.8.2

Subfamily BRACHYCYTHERINAE Puri, 1954

Genus BRACHYCYTHERE Alexander, 1933

BRACHYCYTHERE FORAMINOSA S.L. Alexander, 1934

Figure 2.4.8, Plate 6, figures 7, 8, 9

BRACHYCYTHERE LEDAFORMA (Israelsky, 1929)

Figure 2.5.1

BRACHYCYTHERE OVATA (Berry, 1925)

Figure 2.5.2, Plate 9, figure 1

BRACHYCYTHERE PLENA Alexander, 1934

Plate 9, figure 2

BRACHYCYTHERE POROSA Crane, 1965

Plate 6, figure 6

BRACHYCYTHERE RHOMBOIDALIS (Berry, 1925)

Figure 2.5.3

BRACHYCYTHERE RHOMBOIDALIS (RIDGE FORM) (Berry, 1925)

Plate 1, figure 9

Genus OPIMOCYTHERE Hazel, 1968

OPIMOCYTHERE HAZELI Smith, 1978

Plate 9, figure 4

OPIMOCYTHERE AFF. O. HAZELI Smith, 1978

Subfamily BUNTONIINAE Apostolescu, 1961

Genus PHACORHABDOTUS Howe & Laurencich, 1958

PHACORHABDOTUS FORMOSUS (Alexander, 1934)

Plate 11, figure 8

PHACORHABDOTUS AFF. P. FORMOSUS (Alexander, 1934)

Plate 11, figures 9 and 10

PHACORHABDOTUS SCULPTILIS (Alexander, 1934)

Plate 11, figure 7

Genus SOUDANELLA Apostolescu, 1961

SOUDANELLA PARALLELOPORA Smith, 1978

Plate 6, figure 5

SOUDANELLA SP. A

SOUDANELLA SP. B

Subfamily CAMPYLOCYTHERINAE Puri, 1960

Tribe LEGUMINOCYTHERINI Howe, 1961

Genus ANTICYTHEREIS van den Bold, 1946

ANTICYTHEREIS COPELANDI Smith, 1978

Plate 2, figure 2

ANTICYTHEREIS SP. 1

Plate 3, figure 5

ANTICYTHEREIS SP. 2

ANTICYTHEREIS SP. 3

Plate 2, figure 5

ANTICYTHEREIS SP. 4

Plate 2, figures 3 and 4

ANTICYTHEREIS SP. 5

ANTICYTHEREIS SP. 6

Plate 3, figure 6

ANTICYTHEREIS SP. 7

Plate 2, figure 6

ANTICYTHEREIS SP. 8

ANTICYTHEREIS SP. 9

ANTICYTHEREIS SP. 10

ANTICYTHEREIS SP. 11

ANTICYTHEREIS SP. 12

Plate 2, figure 1

ANTICYTHEREIS SP. 13

ANTICYTHEREIS SP. 14

ANTICYTHEREIS SP. 15

ANTICYTHEREIS SP. 16

Plate 3, figure 3

ANTICYTHEREIS SP. 17

Plate 9, figure 9

ANTICYTHEREIS SP. 18

ANTICYTHEREIS SP. 19

Plate 3, figure 4

Family HEMICYTHERIDAE Puri, 1953

Subfamily THAEROCYTHERINAE Hazel, 1967

Tribe THAEROCYTHERINI Hazel, 1967

Genus HERMANITES Puri, 1955

HERMANITES CF. H. PLUSCULMENSIS (Schmidt, 1948)

Plate 10, figure 7

HERMANITES GIBSONI Hazel, 1968

Plate 10, figure 8

Tribe BRADLEYINI Benson, 1972

Genus LIMBURGINA Deroo, 1966

LIMBURGINA FORESTERAE Smith, 1978

Plate 8, figures 1-5

Family LOXOCONCHIDAE Sars, 1925

Genus LOXOCONCHA Sars, 1866

LOXOCONCHA CLINOCOSTA Crane, 1965

Figure 2.7.6

LOXOCONCHA CORRUGATA Alexander, 1934

Plate 10, figure 6

LOXOCONCHA CRETACEA Alexander, 1936

Figure 2.7.7

LOXOCONCHA DIGITINOTA Crane, 1965

LOXOCONCHA ERECTICOSTA Crane, 1965

LOXOCONCHA FLETCHERI Israelsky, 1929

LOXOCONCHA MINARDI Brouwers & Hazel, 1978

LOXOCONCHA N. SP. A

LOXOCONCHA N. SP.B

LOXOCONCHA NUDA Alexander, 1934

LOXOCONCHA PLEGMA Crane, 1965

LOXOCONCHA STRIATA Crane, 1965

Plate 4, figure 10

Family CYTHERURIDAE G. W. Müller, 1894

Subfamily CYTHERURINAE G. W. Müller, 1894

Genus CYTHERURA Sars, 1866

CYTHERURA CRETACEA Alexander, 1936

Figure 2.6.4

Genus EUCYTHERURA G. W. Müller, 1894

EUCYTHERURA AFF. E. RETICULATA (Smith, 1978)

Plate 10, figures 3 and 4

EUCYTHERURA RETICULATA (Smith, 1978)

Genus ORTHONOTACYTHERE Alexander, 1933

ORTHONOTACYTHERE HANNAI (Israelsky, 1929)

Figure 2.7.8

ORTHONOTACYTHERE CRISTATA Alexander, 1934

Plate 11, figure 2

Subfamily CYTHEROPTERINAE Hanai, 1957

Genus AVERSOVALVA Hornibrook, 1952

AVERSOVALVA ARRECTIHYPHA Crane, 1965

AVERSOVALVA FOSSATA (Skinner, 1956)

Figure 2.6.3

AVERSOVALVA HARRISI

Genus CYTHEROPTERON Sars, 1866

CYTHEROPTERON CASTORENSIS Butler & Jones, 1957

Figure 2.5.8

CYTHEROPTERON CORYELLI Schmidt, 1948

CYTHEROPTERON NAVARROENSE Alexander, 1929

Figure 2.6.1 and 2.6.2

CYTHEROPTERON N. SP. A

CYTHEROPTERON TYPE B Smith, 1978

Family XESTOLEBERIDIDAE Sars, 1928

Genus XESTOLEBERIS Sars, 1866

XESTOLEBERIS OPINA Schmidt, 1948

Plate 6, figure 4

XESTOLEBERIS SEMINULATA Crane, 1965

XESTOLEBERIS SP 1

XESTOLEBERIS SP 2

XESTOLEBERIS SP 3

XESTOLEBERIS SP 4

Family BYTHOCYTHERIDAE Sars, 1866

Genus BYTHOCERATINA Hornibrook, 1952

BYTHOCERATINA AFF. B. ACANTHOPTERA (Marsson, 1880)

Plate 5, figure 3

BYTHOCERATINA AFF. B. UMBONATA (Williamson, 1848)

Plate 5, figure 2

Genus CUNEOCERATINA Gründel and Kozur, 1971

CUNEOCERATINA AFF. C. PEDATA (Marsson, 1880)

Plate 5, figure 4

CUNEOCERATINA AFF. C. PROTHROENSIS (Butler & Jones, 1957)

Plate 5, figure 5

CUNEOCERATINA N. SP. F

Plate 5, figure 8

CUNEOCERATINA PROTHROENSIS (Butler & Jones, 1957)

Genus MONOCERATINA Roth, 1928

"MONOCERATINA" SP. A

Plate 5, figure 7

"MONOCERATINA" SP. C

Plate 5, figure 1

"MONOCERATINA" SP. D

Plate 5, figure 9

"MONOCERATINA" AFF. "M." NITIDA (Alexander, 1934)

Plate 5, figure 10

Superfamily CYPRIDACEA Baird, 1845

Family MACROCYPRIDIDAE G.W. Müller, 1912

Genus MACROCYPRIS Brady, 1867

MACROCYPRIS SP 1

MACROCYPRIS SP 2

MACROCYPRIS SP 3

MACROCYPRIS SP 4

Family PONTOCYPRIDIDAE G.W. Müller, 1894

Genus ARGILLOECIA Sars, 1866

ARGILLOECIA SP. 1

ARGILLOECIA SP. 2

ARGILLOECIA SP. 3

Family CANDONIDAE Kaufmann, 1900

Subfamily PARACYPRIDINAE Sars, 1923

Genus PARACYRPIS Sars, 1866

PARACYRPIS PERAPICULATA Alexander, 1934

PARACYRPIS SP.1

PARACYRPIS SP.2

PARACYRPIS SP.3

PARACYRPIS SP.4

APPENDIX III

SAMPLE LOCALITIES AND STRATIGRAPHIC POSITIONS

Sample no.	Formation	Position (above base = above base of that formation unless indicate otherwise)	County, State	Location
25988	Providence	above 28441	Clay, Georgia	12.9 miles below Eufaula
25993	Providence	same level as 27559	Barbour-Henry Co. line	White Oak Creek
27524	Providence	about 20 feet above base	Barbour, Alabama	Chenneyhatchee Creek
27559	Providence	above 28426	Henry, Alabama	Chattahoochee River
27899	Providence	about 20 feet above base	Barbour, Alabama	Chenneyhatchee Creek
27909	Providence	about 14 feet above base	Barbour, Alabama	Chenneyhatchee Creek
28425	Alexander Ldg. Bed	above 28424	Clay,GA	Chattahoochee River
28426	Providence	"above 28425, contact Prov-Alex. ldg bed"	Henry, Alabama	Chattahoochee River
28441	Providence	above 27559		White Oak Creek
30656	Clayton	reworked Prairie Bluff bed base Clayton	Lowndes, Alabama	Braggs
30660	Prairie Bluff	refer to map PS-75-5, possible middle Prairie Bluff	Lowndes, Alabama	Braggs
30664	Prairie Bluff	immediately above 30663	Lowndes, Alabama	Braggs
30681	Prairie Bluff	about 10 feet above base	Pike	Pike Co.
30734	Prairie Bluff	about 40 feet below K/T boundary	Wilcox/ Dallas	Same as 30733
30735	Prairie Bluff	about 30 feet below K/T boundary	Wilcox/ Dallas	Same as 30733
30736	Prairie Bluff	about 28 feet below K/T boundary	Wilcox/ Dallas	Same as 30733
30761	Owl Creek	type section Owl Creek 15 feet below Clayton	Union	"Tippan Co., Type section"
31354	Providence	base Providence	Barbour, Alabama	Barbour Co.
31428	Prairie Bluff	Upper part Prairie Bluff within 10 feet of K/T boundary	Noxubee	Noxubee Co.
31500	Prairie Bluff	a few feet higher than 31502	Sumter, Alabama	Sumter Co.
31502	Prairie Bluff	Lower Prairie Bluff about 10 feet above base	Sumter, Alabama	Sumter Co.
31504	Prairie Bluff	Lower Prairie Bluff		Sumter Co.

31516	Prairie Bluff	0-1.5 feet below K/T boundary	Sumter, Alabama	Sumter Co.
31517	Prairie Bluff	just below K/T boundary	Sumter, Alabama	Sumter Co.
31595	Prairie Bluff	1-2.5 feet bolew K/T boundary	Sumter, Alabama	Sumter Co.
31596	Prairie Bluff/Clayton	basal Clayton reworked zone	Sumter, Alabama	Same as 31595
31598	Prairie Bluff	upper part Prairie Bluff	Sumter, Alabama	Coatopa Creek Sumter Co.
31600	Prairie Bluff	2 feet 8 inches below K/T boundary	Sumter, Alabama	"Sucarnoochee River, Sumter Co."
31602	Prairie Bluff	3-4 feet below Clayton upper part of PB	Sumter, Alabama	"Sucarnoochee River, Sumter Co."
31603	Prairie Bluff/Clayton	reworked zone lower 1.5 feet of Clayton	Sumter, Alabama	"Sucarnoochee River, Sumter Co."
31761	Prairie Bluff	Lower part Prairie Bluff near base	Noxubee	Lynn Creek Noxubee Co.
31765	Prairie Bluff	Lower part Prairie Bluff, close to the base of Prairie Bluff	Oktibbeha	Same as 31764
32209	Prairie Bluff	Lower Prairie Bluff (1.5 feet lower than 31461)	Marengo	"Tombigbee River,Marengo Co."
32210	Prairie Bluff	1-2 feet below K/T boundary	Sumter, Alabama	"Sucarnoochee River, Sumter Co."
32211	Prairie Bluff	lower 1 foot of Clayton	Sumter, Alabama	Same as 32210
32213	Prairie Bluff	0-4 feet below K/T boundary	Sumter, Alabama	"Sucarnoochee River, Sumter Co.
32346	Prairie Bluff	8 feet above base Prairie Bluff	Pontotoc	Same as 32345
32347	Prairie Bluff	middle PB, 40 ft above Chiwapa Sd	Union	Union Co.
32348	Prairie Bluff	middle Prairie Bluff 4 feet above 32347	Union	Same as 32347
32349	Prairie Bluff	Mid Prairie Bluff 15 feet above base section	Union	Same as 32347
32351	Chiwapa Mbr.	Uppermost Ripley or Lower Chiwapa	Union	Union Co.
32359	Chiwapa Mbr.	Chiwapa sandstone	Union	Union Co.
32360	Prairie Bluff	7 feet above base Prairie Bluff	Union	Union Co.
32362	Chiwapa Mbr.	10 feet above 32361	Union	Same as 32361
32363	Chiwapa Mbr.	12.5 feet above 32361	Union	Same as 32361

32373	Owl Creek	Owl Creek lower 2 feet	Tippah	Same as 32372
32375	Prairie Bluff/Clayton	basal reworked Clayton	Tippah	Same as 32372
32376	Prairie Bluff	Lower Prairie Bluff, about lower 15 ft	Union	Union Co.
32390	Prairie Bluff	20 feet above base	Pontotoc	Pontotoc Co.
32406	Prairie Bluff	either Upper Ripley or Lower Prairie Bluff		Chickasaw Co.
32410	Prairie Bluff	Lower Prairie Bluff, same level as 32412	Chickasaw	Chickasaw Co.
32412	Prairie Bluff	below 32419, basal part, less than 9 ft	Chickasaw	Chickasaw Co.
32413	Prairie Bluff	Lower Prairie Bluff above 32412	Chickasaw	Same as 32412
32414	Prairie Bluff	Mid Prairie Bluff (above 32417) 20'-25' from base PB	Chickasaw	Clay Co.
32416	Prairie Bluff	10 feet above 32414	Chickasaw	Same as 32414
32417	Prairie Bluff	Prairie Bluff about 9 feet	Clay	Clay Co.
32418	Prairie Bluff	basal bed Prairie Bluff, lower 1 ft	Clay	Clay Co.
32419	Prairie Bluff	Lower Prairie Bluff, 9 ft above base	Clay	SAme as 32418
32880	Prairie Bluff	Uppermost Prairie Bluff	Sumter, Alabama	Moscow Landing
32891	Prairie Bluff	phosphatic lag in upper Prairie Bluff"	Sumter, Alabama	"Sucaranoochee River, Sumter Co."
32936	Providence	3 feet above base	Barbour, Alabama	Same as 31354 White Oak Creek
33208	Providence	3 feet above base	Barbour, Alabama	Same as 33207
33209	Providence	12 feet above base	Barbour, Alabama	Same as 33207
33212	Providence	within 10 feet base	Pike	Pike Co.
33213	Providence	about 17 feet above base	Pike	Same as 33212
33214	Providence	Lower Providence 20-25 feet above base	Pike	Pike Co.
33223	Providence	Lower Providence 50 feet above base	Montgomer y	Montgomery Co.
33229	Prairie Bluff	basal bed of Prairie Bluff	Crenshaw	Crenshaw Co.
33233	Prairie Bluff	Upper Prairie Bluff grading up into Providence, 1 foot	Crenshaw	Crenshaw Co.
33234	Prairie Bluff	Upper Prairie Bluff grading up into Providence, 10 feet	Crenshaw	Same as 33233

33236	Prairie Bluff	Upper Prairie Bluff grading up into Providence, 16 feet	Crenshaw	Same as 33233
33239	Prairie Bluff	basal Prairie Bluff	Lowndes, Alabama	Lowndes Co.
33240	Prairie Bluff	about 8 feet above base Prairie Bluff	Lowndes, Alabama	Same as 33239
33243	Prairie Bluff	about 25 feet below Tertiary	Lowndes, Alabama	Lowndes Co.
33248	Prairie Bluff	32 feet above base of Prairie Bluff	Lowndes, Alabama	Lowndes Co.
33249	Prairie Bluff	34 feet above base of Prairie Bluff	Lowndes, Alabama	Same as 33248
33253	Clayton	3-4 feet above Prairie Bluff	Lowndes, Alabama	Lowndes Co.

APPENDIX IV

RELATIVE ABUNDANCE DATA OF OSTRACODE SPECIES

Sample no.	Species	Valves	Percentage
25988	Antibythocypris crassa	2	0.50
25988	Antibythocypris fabaformis	1	0.25
25988	Antibythocypris minuta	47	11.63
25988	Antibythocypris multilira	2	0.50
25988	Brachycythere rhomboidalis	31	7.67
25988	Brachycythere rhomboidalis (ridge form)	3	0.74
25988	Cytherella spp.	40	9.90
25988	Fissocarinocythere pidgeoni	22	5.45
25988	Haplocytheridea everetti	248	61.39
25988	Loxoconcha clinocosta	2	0.50
25988	Loxoconcha cretacea	1	0.25
25988	Loxoconcha minardi	5	1.24
Total		404	100.00
25993	Antibythocypris crassa	5	7.94
25993	Antibythocypris gooberi	2	3.17
25993	Antibythocypris minuta	4	6.35
25993	Antibythocypris multilira	1	1.59
25993	Anticythereis sp. 6	1	1.59
25993	Anticythereis sp. 8	3	4.76
25993	Brachycythere rhomboidalis	14	22.22
25993	Brachycythere rhomboidalis w/ ridge	6	9.52
25993	Cytherella spp.	9	14.29
25993	Fissocarinocythere pidgeoni	1	1.59
25993	Haplocytheridea everetti	12	19.05
25993	Loxoconcha clinocosta	4	6.35
25993	Loxoconcha cretacea	1	1.59
Total		63	100.00
27524	Antibythocypris crassa	11	5.24
27524	Antibythocypris fabaformis	47	22.38
27524	Antibythocypris gooberi	7	3.33
27524	Antibythocypris minuta	16	7.62
27524	Antibythocypris multilira	7	3.33
27524	Antibythocypris pataulensis	6	2.86
27524	Antibythocypris phaseolites	1	0.48
27524	Anticythereis sp. 1	1	0.48
27524	Anticythereis sp. 9	4	1.90
27524	Bairdoppilata magna	2	0.95
27524	Brachycythere ovata	11	5.24
27524	Brachycythere rhomboidalis	39	18.57
27524	Cushmanidea sp. 1	1	0.48
27524	Cushmanidea sp. 2	1	0.48
27524	Cytherella spp.	37	17.62
27524	Haplocytheridea everetti	3	1.43
27524	Haplocytheridea renfroensis	4	1.90
27524	Limburgina foresterae	1	0.48
27524	Loxoconcha clinocosta	2	0.95
27524	Loxoconcha cretacea	9	4.29
Total		210	100.00

Sample no.	Species	Valves	Percentage
27559	Cytherella spp.	16	
Total		16	
27899	Cytherella spp.	2	
27899	Brachycythere ovata	1	
Total		3	
27909	Antibythocypris crassa	5	1.52
27909	Antibythocypris elongata	4	1.22
27909	Antibythocypris fabaformis	49	14.89
27909	Antibythocypris gooberi	11	3.34
27909	Antibythocypris minuta	74	22.49
27909	Antibythocypris multilira	5	1.52
27909	Antibythocypris phaseolites	1	0.30
27909	Anticythereis sp. 11	5	1.52
27909	Anticythereis sp. 9	7	2.13
27909	Bairdoppilata magna	2	0.61
27909	Brachycythere ovata	17	5.17
27909	Brachycythere rhomboidalis	10	3.04
27909	Cytherella spp.	65	19.76
27909	Cytheromorpha cf. C. pittsi	2	0.61
27909	Cytheromorpha cf. C. arbenzi	12	3.65
27909	Eocytheropteron sp.	2	0.61
27909	Escharacytheridea magnamandibulata	2	0.61
27909	Haplocytheridea renfroensis	13	3.95
27909	Limburgina foresterae	2	0.61
27909	Loxoconcha clinocosta	6	1.82
27909	Loxoconcha cretacea	28	8.51
27909	Loxoconcha erecticosta	5	1.52
27909	Paracypris sp. 1	2	0.61
Total		329	100.00
28425	Antibythocypris crassa	3	10.00
28425	Antibythocypris multilira	2	6.67
28425	Bairdia n. sp.	10	33.33
28425	Brachycythere ovata	6	20.00
28425	Curfsina communis	1	3.33
28425	Cytherella spp.	5	16.67
28425	Soundanella?	3	10.00
Total		30	100.00
28426	Antibythocypris multilira	1	1.54
28426	Anticythereis sp. 9	1	1.54
28426	Brachycythere ovata	1	1.54
28426	Brachycythere rhomboidalis	6	9.23
28426	Brachycythere rhomboidalis w/ ridge	6	9.23
28426	Cytherella spp.	6	9.23
28426	Haplocytheridea everetti	42	64.62
28426	Loxoconcha cretacea	2	3.08
Total		65	100.00

Sample no.	Species	Valves	Percentage
28441	Antibythocypris crassa	30	8.55
28441	Antibythocypris elongata	1	0.28
28441	Antibythocypris gooberi	2	0.57
28441	Antibythocypris multilira	7	1.99
28441	Antibythocypris pataulensis	2	0.57
28441	Anticythereis sp. 6	20	5.70
28441	Anticythereis sp. 8	9	2.56
28441	Anticythereis sp. 9	7	1.99
28441	Anticythereis sp. 17	3	0.85
28441	Anticythereis sp. 15	14	3.99
28441	Brachycythere ovata	8	2.28
28441	Brachycythere rhomboidalis	72	20.51
28441	Brachycythere rhomboidalis w/ ridge	2	0.57
28441	Cytherella spp.	21	5.98
28441	Cytheropteron castorensis	4	1.14
28441	Escharacytheridea magnamandibulata	1	0.28
28441	Fissocarinocythere pidgeoni	33	9.40
28441	Haplocytheridea everetti	108	30.77
28441	Loxoconcha clinocosta	3	0.85
28441	Loxoconcha minardi	4	1.14
Total		351	100.00
30656	Cytherella spp.	6	66.67
30656	Brachycythere ovata w/ ridge	1	11.11
30656	Bairdoppilata magna	2	22.22
Total		9	100.00
30660	Antibythocypris crassa	1	0.33
30660	Antibythocypris fabaformis	3	1.00
30660	Antibythocypris minuta	1	0.33
30660	Antibythocypris phaseolites	1	0.33
30660	Ascetoleberis hazardi	1	0.33
30660	Bairdoppilata magna	2	0.66
30660	Brachycythere porosa	5	1.66
30660	Brachycythere ledaforma	18	5.98
30660	Brachycythere ovata	32	10.63
30660	Brachycythere rhomboidalis	84	27.91
30660	Curfsina communis	1	0.33
30660	Cytherella spp.	59	19.60
30660	Escharacytheridea micropunctata	39	12.96
30660	Haplocytheridea everetti	26	8.64
30660	Haplocytheridea renfroensis	27	8.97
30660	Pterygocythere saratogana	1	0.33
Total		301	100.00
30664	Alatacythere ponderosana	6	0.48
30664	Bairdoppilata magna	68	5.45
30664	Bairdia n. sp.2	13	1.04
30664	Brachycythere ovata	209	16.76
30664	Brachycythere rhomboidalis	101	8.10
30664	Brachycythere rhomboidalis w/ ridge	2	0.16

Sample no.	Species	Valves	Percentage
30664	Bythocypris windhami	25	2.00
30664	Cytherella spp.	282	22.61
30664	Pterygocythere saratogana	47	3.77
30664	Alatacythere aff. A. serrata	6	0.48
30664	Antibythocypris gooberi	3	0.24
30664	Argilloecia n. sp. 1	15	1.20
30664	Ascetoleberis hazardi	54	4.33
30664	Brachycythere aff. B. foraminosa	47	3.77
30664	Curfsina communis	100	8.02
30664	Cytherelloidea bicosta s.l.	25	2.00
30664	Cytheropteron coryelli	4	0.32
30664	Eucythere sohli	2	0.16
30664	Fissocarinocythere huntensis	1	0.08
30664	Haplocytheridea everetti	64	5.13
30664	Haplocytheridea globosa	66	5.29
30664	Krithe whitecliffsensis	50	4.01
30664	Loxoconcha digitinota	11	0.88
30664	Loxoconcha striata	15	1.20
30664	Orthonotacythere hannai	1	0.08
30664	Paracypris sp. 1	9	0.72
30664	Paracypris sp. 4	1	0.08
30664	Xestoleberis opina	13	1.04
30664	Xestoleberis seminulata	7	0.56
Total		1247	100.00
30681	Antibythocypris fabaformis	6	15.79
30681	Brachycythere ovata	3	7.89
30681	Brachycythere rhomboidalis	1	2.63
30681	Cytherella spp.	8	21.05
30681	Escharacytheridea micropunctata	9	23.68
30681	Haplocytheridea renfroensis	3	7.89
30681	Krithe whitecliffsensis	2	5.26
30681	Brachycythere aff. B. leda porosa	6	15.79
Total		38	100.00
30734	Alatacythere aff. A. serrata	6	0.37
30734	Alatacythere ponderosana	2	0.12
30734	Amphicytherura curta	32	2.00
30734	Antibythocypris crassa	4	0.25
30734	Antibythocypris fabaformis	5	0.31
30734	Antibythocypris gooberi	36	2.25
30734	Antibythocypris minuta	7	0.44
30734	Antibythocypris multilira	5	0.31
30734	Anticythereis sp. 3	4	0.25
30734	Anticythereis sp. 4	4	0.25
30734	Anticythereis copelandi	2	0.12
30734	Argilloecia n. sp. 1	1	0.06
30734	Ascetoleberis hazardi	81	5.05
30734	Aversovalva fossatum	3	0.19
30734	Bairdoppilata magna	4	0.25
30734	Bairdia w/	2	0.12

Sample no.	Species	Valves	Percentage
30734	Brachycythere foraminosa	108	6.74
30734	Brachycythere ledaforma	131	8.17
30734	Brachycythere ovata	74	4.62
30734	Brachycythere rhomboidalis	122	7.61
30734	Bythocypris n. sp.3	2	0.12
30734	Curfsina communis	104	6.49
30734	"Planileberis" cf. "P." costatana	13	0.81
30734	Cytherella spp.	209	13.04
30734	Cytherelloidea bicosta s.l.	61	3.81
30734	Cytheropteron navarroense	11	0.69
30734	Escharacytheridea magnamandibulata	2	0.12
30734	Escharacytheridea micropunctata	124	7.74
30734	Fissocarinocythere huntensis	46	2.87
30734	Fissocarinocythere pidgeoni	3	0.19
30734	Haplocytheridea everetti	126	7.86
30734	Haplocytheridea renfroensis	36	2.25
30734	Krithe whitecliffsensis	20	1.25
30734	Limburgina foresterae	27	1.68
30734	Loxoconcha clinocosta	3	0.19
30734	Loxoconcha cretacea	3	0.19
30734	Loxoconcha erecticosta	8	0.50
30734	Orthonotacythere hannai	64	3.99
30734	Paracypris sp. 2	10	0.62
30734	Platycosta lixula	33	2.06
30734	Pterygocythere saratogana	18	1.12
30734	Veenia adkinsi	24	1.50
30734	Xestoleberis n. sp. 1	6	0.37
30734	Xestoleberis opina	6	0.37
30734	Xestoleberis seminulata	11	0.69
Total		1603	100.00
30735	Amphicytherura curta	23	1.18
30735	Antibythocypris crassa	1	0.05
30735	Antibythocypris fabaformis	1	0.05
30735	Antibythocypris gooberi	11	0.56
30735	Anticythereis sp. 7	7	0.36
30735	Anticythereis sp. 4	1	0.05
30735	Anticythereis copelandi	1	0.05
30735	Argilloecia n. sp. 1	4	0.21
30735	Argilloecia n. sp. 2	2	0.10
30735	Ascetoleberis hazardi	86	4.41
30735	Aversovalva fossata s.l.	6	0.31
30735	Bairdoppilata magna	1	0.05
30735	Brachycythere foraminosa	83	4.26
30735	Brachycythere ledaforma	136	6.98
30735	Brachycythere ovata	59	3.03
30735	Brachycythere rhomboidalis	218	11.19
30735	Bythocypris n. sp.3	3	0.15
30735	Curfsina communis	147	7.54
30735	"Planileberis" cf. "P." costatana	2	0.10
30735	Cytherella spp.	226	11.60

Sample no.	Species	Valves	Percentage
30735	Cytherelloidea bicosta s.l.	23	1.18
30735	Cytheropteron coryelli	2	0.10
30735	Cytheropteron navarroense	1	0.05
30735	Escharacytheridea micropunctata	193	9.90
30735	Eucytherura aff. E. reticulata	7	0.36
30735	Fissocarinocythere huntensis	5	0.26
30735	Fissocarinocythere pidgeoni	5	0.26
30735	Haplocytheridea everetti	124	6.36
30735	Haplocytheridea globosa	1	0.05
30735	Haplocytheridea renfroensis	188	9.65
30735	Krithe whitecliffsensis	21	1.08
30735	Loxoconcha aff. L. nuda	24	1.23
30735	Loxoconcha clinocosta	6	0.31
30735	Loxoconcha cretacea	24	1.23
30735	Loxoconcha erecticosta	20	1.03
30735	Loxoconcha plegma	9	0.46
30735	Orthonotacythere hannai	84	4.31
30735	Paracypris sp. 2	11	0.56
30735	Platycosta lixula	120	6.16
30735	Polylophus asper	12	0.62
30735	Soudanella parallelopora	3	0.15
30735	Veenia adkinsi	2	0.10
30735	Xestoleberis opina	5	0.26
30735	Xestoleberis seminulata	41	2.10
Total		1949	100.00
30736	Alatacythere ponderosana	1	0.12
30736	Amphicytherura curta	7	0.84
30736	Antibythocypris crassa	3	0.36
30736	Antibythocypris gooberi	9	1.08
30736	Antibythocypris minuta	2	0.24
30736	Antibythocypris multilira	1	0.12
30736	Antibythocypris phaseolites	1	0.12
30736	Anticythereis sp. 3	4	0.48
30736	Anticythereis sp. 4	1	0.12
30736	Ascetoleberis hazardi	44	5.27
30736	Bairdoppilata magna	2	0.24
30736	Brachycythere foraminosa	5	0.60
30736	Brachycythere ledaforma	110	13.17
30736	Brachycythere ovata	63	7.54
30736	Brachycythere rhomboidalis	164	19.64
30736	Bythocypris n. sp.3	1	0.12
30736	Curfsina communis	38	4.55
30736	Cytherella spp.	96	11.50
30736	Cytherelloidea bicosta s.l.	28	3.35
30736	Cytheropteron coryelli	1	0.12
30736	Escharacytheridea micropunctata	50	5.99
30736	Fissocarinocythere huntensis	9	1.08
30736	Fissocarinocythere pidgeoni	2	0.24
30736	Haplocytheridea everetti	62	7.43
30736	Haplocytheridea renfroensis	77	9.22

Sample no.	Species	Valves	Percentage
30736	Krithe whitecliffsensis	1	0.12
30736	Limburgina foresterae	3	0.36
30736	Loxoconcha clinocosta	2	0.24
30736	Orthonotacythere hannai	6	0.72
30736	Paracypris sp. 1	3	0.36
30736	Platycosta lixula	3	0.36
30736	Pterygocythere saratogana	4	0.48
30736	Soudanella parallelopora	1	0.12
30736	Veenia adkinsi	27	3.23
30736	Xestoleberis opina	2	0.24
30736	Xestoleberis seminulata	2	0.24
Total		835	100.00
30761	Amphicytherura curta	10	11.24
30761	Antibythocypris crassa	3	3.37
30761	Antibythocypris fabaformis	4	4.49
30761	Antibythocypris gooberi	3	3.37
30761	Antibythocypris minuta	2	2.25
30761	Antibythocypris multilira	3	3.37
30761	Antibythocypris phaseolites	2	2.25
30761	Aversovalva fossata s.l.	2	2.25
30761	Bairdoppilata magna	10	11.24
30761	Brachycythere aff. B. foraminosa	4	4.49
30761	Brachycythere ovata	3	3.37
30761	Bythocypris n. sp.3	2	2.25
30761	Curfsina communis	7	7.87
30761	Cytherella spp.	10	11.24
30761	Cytherelloidea cf. bicosta	2	2.25
30761	Escharacytheridea magnamandibulata	1	1.12
30761	Escharacytheridea micropunctata	1	1.12
30761	Haplocytheridea bruceclarki	9	10.11
30761	Loxoconcha renfroensis	2	2.25
30761	Loxoconcha striata	2	2.25
30761	Xestoleberis opina	7	7.87
Total		89	100.00
31354	Cytherella spp.	5	9.26
31354	Brachycythere ovata	6	11.11
31354	Brachycythere rhomboidalis	13	24.07
31354	Bairdoppilata magna	2	3.70
31354	Curfsina communis	2	3.70
31354	Cytherella	5	9.26
31354	Escharacytheridea pinochii	2	3.70
31354	Haplocytheridea everetti	11	20.37
31354	Haplocytheridea renfroensis	1	1.85
31354	Krithe whitecliffsensis	3	5.56
31354	Loxoconcha cretacea	4	7.41
Total		54	100.00
31428	Alatacythere aff. A. serrata	4	0.68
31428	Alatacythere ponderosana	2	0.34

Sample no.	Species	Valves	Percentage
31428	Amphicytherura curta	2	0.34
31428	Bairdoppilata magna	161	27.24
31428	Brachycythere aff. B. foraminosa	12	2.03
31428	Brachycythere ledaforma	20	3.38
31428	Brachycythere ovata	69	11.68
31428	Brachycythere rhomboidalis	16	2.71
31428	Bythocypris windhami	2	0.34
31428	Cuneoceratina aff. C. pedata	1	0.17
31428	Curfsina communis	5	0.85
31428	Cytherella spp.	113	19.12
31428	Cytherelloidea crafti	11	1.86
31428	Cytheropteron castorensis	2	0.34
31428	Escharacytheridea pinochii	2	0.34
31428	Eucythere aff. E. brightseat B&J	1	0.17
31428	Fissocarinocythere huntensis	5	0.85
31428	Haplocytheridea bruceclarki	2	0.34
31428	Haplocytheridea globosa	46	7.78
31428	Haplocytheridea renfroensis	32	5.41
31428	Haplocytheridea renfroensis (large)	18	3.05
31428	Krithe whitecliffsensis	27	4.57
31428	"Monoceratina" n. sp. A	1	0.17
31428	"Monoceratina" prothroensis	3	0.51
31428	Orthonotacythere hannai	1	0.17
31428	Pterygocythere saratogana	5	0.85
31428	Sphaeroleberis pseudo	2	0.34
31428	Veenia parallelopora	9	1.52
31428	Xestoleberis n. sp. 2	4	0.68
31428	Xestoleberis opina	11	1.86
31428	Xestoleberis seminulata	2	0.34
Total		591	100.00
31500	Alatacythere ponderosana	7	1.32
31500	Antibythocypris gooberi	7	1.32
31500	Ascetoleberis hazardi	19	3.58
31500	Bairdoppilata magna	47	8.87
31500	Brachycythere aff. B. foraminosa	2	0.38
31500	Brachycythere ledaforma	18	3.40
31500	Brachycythere ovata	93	17.55
31500	Brachycythere rhomboidalis	27	5.09
31500	Bythocypris windhami	3	0.57
31500	Curfsina communis	31	5.85
31500	"Planileberis" cf. "P." costatana	18	3.40
31500	Cytherella spp.	71	13.40
31500	Cytherelloidea bicosta s.l.	15	2.83
31500	Cytherelloidea n. sp.	6	1.13
31500	Cytheropteron castorensis	2	0.38
31500	Cytheropteron coryelli	2	0.38
31500	Cytheropteron guadalupensis	2	0.38
31500	Fissocarinocythere huntensis	3	0.57
31500	Haplocytheridea bruceclarki	15	2.83
31500	Haplocytheridea everetti	31	5.85

Sample no.	Species	Valves	Percentage
31500	Haplocytheridea globosa	27	5.09
31500	Haplocytheridea renfroensis	2	0.38
31500	Haplocytheridea renfroensis (large)	56	10.57
31500	Krithe whitecliffsensis	16	3.02
31500	Limburgina foresterae	1	0.19
31500	Macrocypris sp. 1	1	0.19
31500	Paracypris sp. 4	5	0.94
31500	Veenia ponderosana	1	0.19
31500	Xestoleberis opina	2	0.38
Total		530	100.00
31502	Alatacythere ponderosana	2	0.15
31502	Bairdoppilata magna	141	10.28
31502	Brachycythere aff. B. foraminosa	97	7.08
31502	Brachycythere ledaforma	50	3.65
31502	Brachycythere ovata	212	15.46
31502	Brachycythere rhomboidalis	121	8.83
31502	Bythocypris n. sp.1	5	0.36
31502	Bythocypris n. sp.2	1	0.07
31502	Bythocypris windhami	6	0.44
31502	Curfsina communis	42	3.06
31502	"Planileberis" cf. "P." costatana	7	0.51
31502	Cytherella spp.	264	19.26
31502	Cytherelloidea crafti	66	4.81
31502	Cytherelloidea n. sp.	3	0.22
31502	Cytheropteron castoensis	4	0.29
31502	Escharacytheridea pinochii	88	6.42
31502	Fissocarinocythere huntensis	21	1.53
31502	Haplocytheridea bruceclarki	4	0.29
31502	Haplocytheridea everetti	28	2.04
31502	Haplocytheridea globosa	41	2.99
31502	Haplocytheridea renfroensis (large)	33	2.41
31502	Krithe whitecliffsensis	27	1.97
31502	Limburgina foresterae	1	0.07
31502	Macrocypris sp. 1	4	0.29
31502	"Monoceratina" aff. "M." prothroensis	1	0.07
31502	"Monoceratina" n. sp. B	3	0.22
31502	"Monoceratina" n. sp. C	2	0.15
31502	"Monoceratina" n. sp. D	2	0.15
31502	"Monoceratina" n. sp. E	1	0.07
31502	Orthonotacythere hannai	3	0.22
31502	Paracypris sp. 4	7	0.51
31502	Pterygocythere saratogana	23	1.68
31502	Veenia ponderosana	47	3.43
31502	Xestoleberis opina	14	1.02
Total		1371	100.00
31504	Alatacythere ponderosana	8	1.00
31504	Antibythocypris gooberi	2	0.25
31504	Bairdoppilata magna	147	18.40
31504	Bairdia n. sp.2	18	2.25

Sample no.	Species	Valves	Percentage
31504	Brachycythere aff. B. foraminosa	15	1.88
31504	Brachycythere ledaforma	15	1.88
31504	Brachycythere ovata	65	8.14
31504	Brachycythere rhomboidalis	28	3.50
31504	Bythocypris n. sp.1	1	0.13
31504	Bythocypris windhami	11	1.38
31504	Curfsina communis	37	4.63
31504	"Planileberis" cf. "P." costatana	6	0.75
31504	Cytherella spp.	208	26.03
31504	Cytheropteron navarroense	6	0.75
31504	Escharacytheridea pinochii	13	1.63
31504	Fissocarinocythere huntensis	2	0.25
31504	Haplocytheridea bruceclarki	6	0.75
31504	Haplocytheridea everetti	79	9.89
31504	Haplocytheridea globosa	76	9.51
31504	Haplocytheridea renfroensis	16	2.00
31504	Macrocypris sp. 1	1	0.13
31504	"Monoceratina" n. sp. C	8	1.00
31504	"Monoceratina" n. sp. D	7	0.88
31504	Paracypris sp. 4	1	0.13
31504	Pterygocythere saratogana	8	1.00
31504	Veenia arachoides	1	0.13
31504	Veenia ponderosana	8	1.00
31504	Xestoleberis opina	6	0.75
Total		799	100.00
31516	Barren		
31517	Antibythocypris gooberi	6	1.79
31517	Bairdoppilata magna	26	7.76
31517	Brachycythere aff. B. foraminosa	3	0.90
31517	Brachycythere ovata	34	10.15
31517	Brachycythere rhomboidalis	29	8.66
31517	Bythocypris windhami	9	2.69
31517	Cuneoceratina aff. C. pedata	1	0.30
31517	Curfsina communis	9	2.69
31517	"Planileberis" cf. "P." costatana	7	2.09
31517	Cytherella spp.	108	32.24
31517	Cytherelloidea bicosta s.l.	38	11.34
31517	Cytheropteron navarroense	2	0.60
31517	Eucythere sohli	2	0.60
31517	Fissocarinocythere huntensis	9	2.69
31517	Haplocytheridea bruceclarki	1	0.30
31517	Krithe whitecliffsensis	7	2.09
31517	"Monoceratina" prothroensis	1	0.30
31517	Pterygocythere saratogana	28	8.36
31517	Veenia parallelopora	9	2.69
31517	Xestoleberis opina	4	1.19
31517	Xestoleberis seminulata	2	0.60
Total		335	100.00

Sample no.	Species	Valves	Percentage
31595	Alatacythere ponderosana	10	1.05
31595	Antibythocypris gooberi	37	3.88
31595	Argilloecia n. sp. 1	1	0.10
31595	Ascetoleberis hazardi	19	1.99
31595	Bairdoppilata magna	171	17.94
31595	Brachycythere leda porosa	16	1.68
31595	Brachycythere ledaforma	15	1.57
31595	Brachycythere ovata	122	12.80
31595	Brachycythere rhomboidalis	36	3.78
31595	Bythocypris windhami	5	0.52
31595	Cuneoceratina aff. C. pedata	5	0.52
31595	Curfsina communis	37	3.88
31595	"Planileberis" cf. "P." costatana	60	6.30
31595	Cytherella spp.	109	11.44
31595	Cytherelloidea austinenesis	14	1.47
31595	Cytherelloidea bicosta	33	3.46
31595	Cytheropteron coryelli	4	0.42
31595	Cytheropteron navarroense	9	0.94
31595	Haplocytheridea bruceclarki	49	5.14
31595	Haplocytheridea everetti	40	4.20
31595	Haplocytheridea globosa	48	5.04
31595	Haplocytheridea renfroensis	33	3.46
31595	Haplocytheridea renfroensis (large)	19	1.99
31595	Krithe whitecliffsensis	12	1.26
31595	Limburgina foresterae	0	0.00
31595	"Monoceratina" aff. "M." prothroensis	1	0.10
31595	"Monoceratina" n. sp. B	1	0.10
31595	"Monoceratina" n. sp. C	2	0.21
31595	"Monoceratina" n. sp. D	1	0.10
31595	"Monoceratina" n. sp. E	3	0.31
31595	Orthonotacythere hannai	3	0.31
31595	Paracypris sp. 3	2	0.21
31595	Paracypris sp. 4	1	0.10
31595	Phacorhabdotus aff. P. formosus	4	0.42
31595	Pterygocythere saratogana	3	0.31
31595	Veenia ponderosana	14	1.47
31595	Xestoleberis opina	12	1.26
31595	Xestoleberis seminulata	2	0.21
Total		953	100.00
31596	Antibythocypris gooberi	3	2.97
31596	Bairdoppilata magna	15	14.85
31596	Brachycythere aff. B. foraminosa	2	1.98
31596	Brachycythere ovata	3	2.97
31596	Brachycythere plena	11	10.89
31596	Brachycythere rhomboidalis	3	2.97
31596	Bythocypris windhami	1	0.99
31596	"Planileberis" cf. "P." costatana	7	6.93
31596	Cytherella spp.	41	40.59
31596	Haplocytheridea bruceclarki	5	4.95

Sample no.	Species	Valves	Percentage
31596	Haplocytheridea everetti	6	5.94
31596	Haplocytheridea renfroensis	1	0.99
31596	Krithe whitecliffsensis	1	0.99
31596	Loxoconcha n. sp. A	2	1.98
Total		101	100.00
31598	Alatacythere ponderosana(rework)	3	0.22
31598	Antibythocypris gooberi	44	3.24
31598	Anticythereis sp. 4	1	0.07
31598	Bairdoppilata magna	318	23.45
31598	Brachycythere aff. B. foraminosa	23	1.70
31598	Brachycythere ledaforma	100	7.37
31598	Brachycythere ovata	90	6.64
31598	Brachycythere rhomboidalis	35	2.58
31598	Bythocypris windhami	10	0.74
31598	Curfsina communis	48	3.54
31598	"Planileberis" cf. "P." costatana	18	1.33
31598	Cytherella spp.	350	25.81
31598	Cytherelloidea austinenesis	21	1.55
31598	Cytherelloidea bicosta s.l.	10	0.74
31598	Cytherelloidea crafti	7	0.52
31598	Cytheropteron castoensis	2	0.15
31598	Cytheropteron navarroense	9	0.66
31598	Escharacytheridea pinochii	48	3.54
31598	Haplocytheridea everetti	71	5.24
31598	Haplocytheridea globosa	74	5.46
31598	Haplocytheridea renfroensis	9	0.66
31598	Krithe whitecliffsensis	5	0.37
31598	Limburgina foresterae	5	0.37
31598	Bythoceratina aff. B. acanthoptera	1	0.07
31598	"Monoceratina" aff. "M." umbonata	1	0.07
31598	"Monoceratina" n. sp. D	2	0.15
31598	Platycosta lixula	10	0.74
31598	Pterygocythere saratogana	10	0.74
31598	Veenia arachoides	11	0.81
31598	Veenia ponderosana	4	0.29
31598	Xestoleberis opina	16	1.18
Total		1356	100.00
31600	Amphicytherura curta	2	0.34
31600	Antibythocypris gooberi	1	0.17
31600	Ascetoleberis hazardi	7	1.20
31600	Bairdoppilata magna	63	10.81
31600	Brachycythere aff. B. foraminosa	21	3.60
31600	Brachycythere ledaforma	9	1.54
31600	Brachycythere ovata	35	6.00
31600	Brachycythere rhomboidalis	15	2.57
31600	Bythocypris windhami	4	0.69
31600	Cuneoceratina aff. C. pedata	6	1.03
31600	Curfsina communis	17	2.92
31600	"Planileberis" cf. "P." costatana	8	1.37

Sample no.	Species	Valves	Percentage
31600	Cytherella spp.	117	20.07
31600	Cytherelloidea aff. austinenesis	7	1.20
31600	Cytherelloidea bicosta	37	6.35
31600	Cytheropteron navarroense	1	0.17
31600	Escharacytheridea pinochii	1	0.17
31600	Fissocarinocythere huntensis	12	2.06
31600	Haplocytheridea bruceclarki	47	8.06
31600	Haplocytheridea everetti	26	4.46
31600	Haplocytheridea globosa	6	1.03
31600	Haplocytheridea renfroensis	26	4.46
31600	Krithe aff. K. whitecliffsensis	4	0.69
31600	Krithe whitecliffsensis	3	0.51
31600	Loxoconcha fletcheri	2	0.34
31600	Monoceratina aff. M. prothroensis	1	0.17
31600	Monoceratina n. sp. C	1	0.17
31600	Monoceratina n. sp. D	4	0.69
31600	Monoceratina n. sp. F	7	1.20
31600	Paracypris sp. 4	3	0.51
31600	Pterygocythere saratogana	6	1.03
31600	Pterygocythere saratogana	4	0.69
31600	Sphaeroleberis pseudoconcentrica	1	0.17
31600	Veenia adkinsi	3	0.51
31600	Veenia adkinsi	13	2.23
31600	Veenia parallelopora	6	1.03
31600	Veenia ponderosana	1	0.17
31600	Xestoleberis opina	43	7.38
31600	Xestoleberis seminulata	13	2.23
Total		583	100.00
31602	Cytherella spp.	157	19.65
31602	Ascetoleberis hazardi	13	1.63
31602	Brachycythere foraminosa	5	0.63
31602	Brachycythere ledafroma	45	5.63
31602	Brachycythere ovata w/ ridge	30	3.75
31602	Brachycythere rhomboidalis	25	3.13
31602	Bairdoppilata magna	53	6.63
31602	Curfsina communis	34	4.26
31602	Cytherella	140	17.52
31602	Cytherelloidea bicosta	9	1.13
31602	Cytheropteron navarroense	7	0.88
31602	Escharacytheridea micropunctata	23	2.88
31602	Haplocytheridea everetti	77	9.64
31602	Haplocytheridea globosa	8	1.00
31602	Haplocytheridea renfroensis	145	18.15
31602	Krithe whitecliffsensis	3	0.38
31602	Macrocypris n. sp. 1	6	0.75
31602	"Monoceratina" n. sp. C	2	0.25
31602	Orthonotacythere hannai	8	1.00
31602	Pterygocythere saratogana	3	0.38
31602	Veenia parallelopora	6	0.75
Total		799	100.00

Sample no.	Species	Valves	Percentage
31603	Bairdoppilata magna	71	14.03
31603	Brachycythere aff. B. foraminosa	6	1.19
31603	Brachycythere ledaforma	13	2.57
31603	Brachycythere ovata	50	9.88
31603	Brachycythere rhomboidalis	17	3.36
31603	Cytherella spp.	112	22.13
31603	Amphicytherura curta	2	0.40
31603	Antibythocypris crassa	12	2.37
31603	Antibythocypris gooberi	4	0.79
31603	Antibythocypris minuta	4	0.79
31603	Antibythocypris multilira	3	0.59
31603	Anticythereis sp. 10	2	0.40
31603	Anticythereis sp. 3	1	0.20
31603	Anticythereis sp. 4	6	1.19
31603	Ascetoleberis hazardi	2	0.40
31603	Bythocypris windhami	3	0.59
31603	Curfsina communis	39	7.71
31603	"Planileberis" cf. "P." costatana	4	0.79
31603	Cytherelloidea bicosta	16	3.16
31603	Cytheropteron navarroense	2	0.40
31603	Escharacytheridea pinochii	10	1.98
31603	Fissocarinocythere huntensis	4	0.79
31603	Haplocytheridea bruceclarki	11	2.17
31603	Haplocytheridea everetti	21	4.15
31603	Haplocytheridea globosa	13	2.57
31603	Haplocytheridea renfroensis	50	9.88
31603	Krithe whitecliffsensis	4	0.79
31603	Limburgina foresterae	4	0.79
31603	Orthonotacythere hannai	3	0.59
31603	Phacorhabdotus aff. P. formosus	4	0.79
31603	Pterygocythere saratogana	2	0.40
31603	Veenia adkinsi	1	0.20
31603	Veenia arachoides	2	0.40
31603	Veenia parallelopora	2	0.40
31603	Xestoleberis opina	5	0.99
31603	Xestoleberis seminulata	1	0.20
Total		506	100.00
31761	Brachycythere ovata	22	8.56
31761	Cytherella spp.	234	91.05
31761	Orthonotacythere hannai	1	0.39
Total		257	100.00
31765	Alatacythere ponderosana	1	0.21
31765	Amphicytherura curta	1	0.21
31765	Antibythocypris fabaformis	1	0.21
31765	Antibythocypris gooberi	61	12.58
31765	Antibythocypris minuta	11	2.27
31765	Anticythereis 40	2	0.41
31765	Bairdoppilata magna	109	22.47
31765	Brachycythere aff. B. foraminosa	17	3.51

Sample no.	Species	Valves	Percentage
31765	Brachycythere ledaforma	2	0.41
31765	Brachycythere ovata	56	11.55
31765	Brachycythere rhomboidalis	8	1.65
31765	Bythocypris windhami	1	0.21
31765	Curfsina communis	21	4.33
31765	"Planileberis" cf. "P." costatana	7	1.44
31765	Cytherella spp.	84	17.32
31765	Cytheropteron castoensis	3	0.62
31765	Cytheropteron navarroense	4	0.82
31765	Escharacytheridea pinochii	22	4.54
31765	Fissocarinocythere huntensis	11	2.27
31765	Haplocytheridea bruceclarki	10	2.06
31765	Haplocytheridea everetti	14	2.89
31765	Haplocytheridea globosa	24	4.95
31765	Krithe whitecliffsensis	3	0.62
31765	Limburgina foresterae	3	0.62
31765	Bythoceratina aff. B. acanthoptera	1	0.21
31765	Monoceratina aff. M. nitida	1	0.21
31765	Pterygocythere saratogana	2	0.41
31765	Veenia ponderosana	5	1.03
Total		485	100.00
32209	Bairdoppilata magna	131	12.97
32209	Bairdia n. sp.2	6	0.59
32209	Brachycythere aff. B. foraminosa	28	2.77
32209	Brachycythere ovata	109	10.79
32209	Brachycythere rhomboidalis	27	2.67
32209	Cytherella spp.	190	18.81
32209	Alatacythere ponderosana	6	0.59
32209	Amphicytherura curta	13	1.29
32209	Antibythocypris gooberi	87	8.61
32209	Argilloecia n. sp. 1	5	0.50
32209	Argilloecia n. sp. 2	1	0.10
32209	Aversovalva fossata s.l.	1	0.10
32209	Bythocypris n. sp.2	1	0.10
32209	Bythocypris windhami	7	0.69
32209	Curfsina communis	43	4.26
32209	"Planileberis" cf. "P." costatana	20	1.98
32209	Cytherelloidea crafti	26	2.57
32209	Cytherelloidea inflata	2	0.20
32209	Cytherelloidea spiralia	4	0.40
32209	Cytheropteron navarroense	3	0.30
32209	Escharacytheridea pinochii	67	6.63
32209	Eucythere n. sp.	2	0.20
32209	Fissocarinocythere huntensis	4	0.40
32209	Haplocytheridea bruceclarki	40	3.96
32209	Haplocytheridea everetti	36	3.56
32209	Haplocytheridea renfroensis	17	1.68
32209	Krithe whitecliffsensis	15	1.49
32209	Limburgina foresterae	8	0.79
32209	Loxoconcha clinocosta	1	0.10

Sample no.	Species	Valves	Percentage
32209	Loxoconcha cretacea	13	1.29
32209	Loxoconcha fletcheri	8	0.79
32209	Macrocypris n. sp.1	2	0.20
32209	Bythoceratina aff. B. umbonata	1	0.10
32209	Monoceratina n. sp. A	1	0.10
32209	Monoceratina n. sp. D	2	0.20
32209	Pterygocythere saratogana	6	0.59
32209	Veenia ponderosana	30	2.97
32209	Xestoleberis n. sp. 2	3	0.30
32209	Xestoleberis opina	29	2.87
32209	Xestoleberis seminulata	15	1.49
Total		1010	100.00
32210	Antibythocypris crassa	2	2.67
32210	Antibythocypris gooberi	1	1.33
32210	Bairdoppilata magna	14	18.67
32210	Bairdia n. sp.2	2	2.67
32210	Brachycythere ovata w/ ridge	4	5.33
32210	Brachycythere plena	10	13.33
32210	Cytherella spp.	30	40.00
32210	Phacorhabdotus aff. P. formosus	12	16.00
Total	.	75	100.00
32211	Antibythocypris crassa	1	1.43
32211	Brachycythere plena	9	12.86
32211	Curfsina communis	1	1.43
32211	"Planileberis" cf. "P." costatana	1	1.43
32211	Cytherella spp.	36	51.43
32211	Phacor aff. P. formosa	22	31.43
Total		70	100.00
32213	Argilloecia n. sp.	2	0.35
32213	Brachycythere rhomboidalis	7	1.21
32213	"Planileberis" cf. "P." costatana	17	2.94
32213	Cytherella spp.	168	29.02
32213	Alatacythere ponderosana	6	1.04
32213	Amphicytherura curta	3	0.52
32213	Antibythocypris crassa	1	0.17
32213	Antibythocypris gooberi	3	0.52
32213	Aversovalva harrisi	1	0.17
32213	Brachycythere foraminosa	15	2.59
32213	Brachycythere ledaforma	5	0.86
32213	Bythocypris n. sp.1	2	0.35
32213	Bythocypris windhami	2	0.35
32213	Cuneoceratina aff. C. pedata	3	0.52
32213	Curfsina communis	31	5.35
32213	Cytherelloidea aff. austinenesis	5	0.86
32213	Cytherelloidea bicosta	27	4.66
32213	Cytheropteron coryelli	1	0.17
32213	Eucythere sohli	2	0.35
32213	Fissocarinocythereensis	11	1.90

Sample no.	Species	Valves	Percentage
32213	Haplocytheridea bruceclarki	86	14.85
32213	Haplocytheridea everetti	16	2.76
32213	Krithe whitecliffsensis	29	5.01
32213	Loxoconcha fletcheri	6	1.04
32213	Loxoconcha n. sp. B	3	0.52
32213	Loxoconcha striata	3	0.52
32213	Bythoceratina aff. B. umbonata	1	0.17
32213	Monoceratina n. sp. B	1	0.17
32213	Monoceratina n. sp. E	2	0.35
32213	Monoceratina n. sp. F	3	0.52
32213	Monoceratina prothroensis	4	0.69
32213	Orthonotacythere hannai	1	0.17
32213	Paracypris sp.1	3	0.52
32213	Phacor aff. P. formosa	12	2.07
32213	Platycosta lixula	5	0.86
32213	Veenia adkinsi	15	2.59
32213	Veenia parallelopora	19	3.28
32213	Xestoleberis n. sp. 2	3	0.52
32213	Xestoleberis n. sp. 3	3	0.52
32213	Xestoleberis opina	43	7.43
32213	Xestoleberis seminulata	9	1.55
Total		579	100.00
32346	Alatacythere aff. A. serrata	8	3.01
32346	Amphicytherura curta	2	0.75
32346	Antibythocypris gooberi	4	1.50
32346	Antibythocypris macropora	2	0.75
32346	Ascetoleberis hazardi	3	1.13
32346	Bairdoppilata magna	2	0.75
32346	Brachycythere aff. B. leda porosa	11	4.14
32346	Brachycythere ledaforma	13	4.89
32346	Brachycythere ovata	51	19.17
32346	Brachycythere rhomboidalis	68	25.56
32346	Curfsina communis	17	6.39
32346	Cytherella spp.	13	4.89
32346	Cytheropteron navarroense	1	0.38
32346	Escharacytheridea micropunctata	19	7.14
32346	Fissocarinocythere huntensis	5	1.88
32346	Haplocytheridea bruceclarki	13	4.89
32346	Haplocytheridea renfroensis	8	3.01
32346	Orthonotacythere hannai	6	2.26
32346	Platycosta lixula	4	1.50
32346	Pterygocythere saratogana	8	3.01
32346	Veenia parallelopora	6	2.26
32346	Xestoleberis seminulata	2	0.75
Total		266	100.00
32349	Amphicytherura curta	123	14.25
32349	Antibythocypris crassa	82	9.50
32349	Antibythocypris fabaformis	1	0.12
32349	Antibythocypris gooberi	96	11.12

Sample no.	Species	Valves	Percentage
32349	Antibythocypris minuta	56	6.49
32349	Antibythocypris multilira	18	2.09
32349	Antibythocypris pataulensis	2	0.23
32349	Antibythocypris phaseolites	4	0.46
32349	Antibythocypris. trisulcata	1	0.12
32349	Anticythereis sp. 2	6	0.70
32349	Anticythereis sp. 12	1	0.12
32349	Anticythereis sp. 14	23	2.67
32349	Anticythereis sp. 17	24	2.78
32349	Anticythereis sp. 3	9	1.04
32349	Anticythereis sp. 4	20	2.32
32349	Anticythereis sp. 11	30	3.48
32349	Anticythereis cf. A. sp. 15	3	0.35
32349	Anticythereis copelandi	1	0.12
32349	Bairdia	5	0.58
32349	Bairdoppilata magna	26	3.01
32349	Bairdia n. sp.2	3	0.35
32349	Brachycythere aff. B. leda porosa	30	3.48
32349	Brachycythere ovata	37	4.29
32349	Brachycythere rhomboidalis	4	0.46
32349	Curfsina communis	23	2.67
32349	Cushmanidea w/ round pits	30	3.48
32349	Cytherella spp.	142	16.45
32349	Cytherelloidea n.sp. of Drouant	36	4.17
32349	Cytheropteron castorensis	2	0.23
32349	Cytheropteron cf. type A of Smith	5	0.58
32349	Escharacytheridea magnamandibulata	2	0.23
32349	Escharacytheridea pinochii	2	0.23
32349	Fissocarinocythere huntensis	4	0.46
32349	Limburgina foresterae	4	0.46
32349	Platycosta lixula	8	0.93
Total		863	100.00
32351	Amphicytherura curta	274	30.21
32351	Antibythocypris fabaformis	1	0.11
32351	Antibythocypris gooberi	83	9.15
32351	Antibythocypris minuta	50	5.51
32351	Anticythereis sp. 3	3	0.33
32351	Anticythereis sp. 4	5	0.55
32351	Argilloecia n. sp. 1	1	0.11
32351	Ascetoleberis hazardi	13	1.43
32351	Aversovalva arrectihypha	1	0.11
32351	Bairdoppilata magna	19	2.09
32351	Bairdia n. sp.2	8	0.88
32351	Brachycythere aff. B. leda porosa	141	15.55
32351	Brachycythere leda porosa	4	0.44
32351	Brachycythere ovata	43	4.74
32351	Brachycythere rhomboidalis	43	4.74
32351	Bythocypris windhami	6	0.66
32351	Curfsina communis	52	5.73
32351	Cytherella spp.	100	11.03

Sample no.	Species	Valves	Percentage
32351	Cytheropteron cf. type A of Smith	12	1.32
32351	Escharacytheridea micro	2	0.22
32351	Fissocarinocythere huntensis	3	0.33
32351	Haplocytheridea bruceclarki	10	1.10
32351	Haplocytheridea everetti	3	0.33
32351	Haplocytheridea globosa	5	0.55
32351	Orthonotacythere hannai	1	0.11
32351	Platycosta lixula	21	2.32
32351	Pterygocythere saratogana	2	0.22
32351	Xestoleberis seminulata	1	0.11
Total		907	100.00
32359	Cytherella spp.	1	
32360	Alatacythere aff. A. serrata	4	0.94
32360	Amphicytherura curta	8	1.87
32360	Antibythocypris gooberi	3	0.70
32360	Antibythocypris minuta	2	0.47
32360	Anticythereis sp. 3	1	0.23
32360	Argilloecia n. sp. 2	2	0.47
32360	Bairdoppilata magna	97	22.72
32360	Brachycythere aff. B. foraminosa	9	2.11
32360	Brachycythere ledaforma	4	0.94
32360	Brachycythere ovata	99	23.19
32360	Brachycythere rhomboidalis	80	18.74
32360	Curfsina communis	5	1.17
32360	Cytherella spp.	43	10.07
32360	Cytheropteron navarroense	1	0.23
32360	Escharacytheridea magnamandibulata	3	0.70
32360	Escharacytheridea micro	18	4.22
32360	Escharacytheridea pinochii	4	0.94
32360	Fissocarinocythere huntensis	2	0.47
32360	Haplocytheridea bruceclarki	26	6.09
32360	Krithe whitecliffsensis	6	1.41
32360	Orthonotacythere hannai	6	1.41
32360	Platycosta lixula	1	0.23
32360	Pterygocythere saratogana	2	0.47
32360	Xestoleberis opina	1	0.23
Total		427	100.00
32362	Amphicytherura curta	2	1.89
32362	Antibythocypris minuta	1	0.94
32362	Anticythereis sp. 14	2	1.89
32362	Anticythereis sp. 16	3	2.83
32362	Anticythereis sp. 4	6	5.66
32362	Anticythereis copelandi	1	0.94
32362	Ascetoleberis hazardi	1	0.94
32362	Bairdoppilata magna	4	3.77
32362	Bairdia n. sp.2	2	1.89
32362	Brachycythere aff. B. leda porosa	9	8.49
32362	Brachycythere ovata	1	0.94

Sample no.	Species	Valves	Percentage
32362	Brachycythere rhomboidalis w/ ridge	7	6.60
32362	Bythocypris windhami	21	19.81
32362	Curfsina communis	8	7.55
32362	Cytherella spp.	26	24.53
32362	Cytherelloidea aff. crafti	4	3.77
32362	Cytheropteron cf. type A of Smith	1	0.94
32362	Limburgina foresterae	4	3.77
32362	Macrocypris n. sp.1	2	1.89
32362	Paracypris sp. 4	1	0.94
Total		106	100.00
32363	Amphicytherura curta	103	26.61
32363	Antibythocypris crassa	2	0.52
32363	Antibythocypris gooberi	13	3.36
32363	Antibythocypris minuta	4	1.03
32363	Anticythereis sp. 14	6	1.55
32363	Anticythereis sp. 4	7	1.81
32363	Ascetoleberis hazardi	1	0.26
32363	Bairdoppilata magna	14	3.62
32363	Bairdia n. sp.2	6	1.55
32363	Brachycythere aff. B. foraminosa	13	3.36
32363	Brachycythere aff. B. leda porosa	58	14.99
32363	Brachycythere rhomboidalis	24	6.20
32363	Bythocypris windhamihami	5	1.29
32363	Curfsina communis	27	6.98
32363	Cytherella spp.	65	16.80
32363	Cytherelloidea aff. bicosta	15	3.88
32363	Cytheropteron cf. type A of Smith	1	0.26
32363	Escharacytheridea magnamandibulata	1	0.26
32363	Escharacytheridea pinochii	1	0.26
32363	Eucythere n. sp.	1	0.26
32363	Fissocarinocythere huntensis	7	1.81
32363	Haplocytheridea bruceclarki	2	0.52
32363	Haplocytheridea everetti	2	0.52
32363	Haplocytheridea globosa	3	0.78
32363	Platycosta lixula	6	1.55
Total		387	100.00
32373	Amphicytherura curta	25	28.09
32373	Antibythocypris crassa	3	3.37
32373	Antibythocypris fabaformis	4	4.49
32373	Antibythocypris gooberi	13	14.61
32373	Antibythocypris minuta	2	2.25
32373	Antibythocypris multilira	2	2.25
32373	Anticythereis sp. 17	2	2.25
32373	Bairdoppilata magna	2	2.25
32373	Brachycythere ovata	3	3.37
32373	Brachycythere rhomboidalis	4	4.49
32373	Curfsina communis	17	19.10
32373	Cytherella spp.	3	3.37
32373	Cytherelloidea bicosta	3	3.37

Sample no.	Species	Valves	Percentage
32373	Haplocytheridea bruceclarki	6	6.74
Total		89	100.00
32375	Barren		
32376	Alatacythere aff. A. serrata	2	0.33
32376	Amphicytherura curta	49	8.06
32376	Antibythocypris gooberi	93	15.30
32376	Antibythocypris minuta	33	5.43
32376	Argilloecia n. sp. 1	7	1.15
32376	Argilloecia n. sp. 2	1	0.16
32376	Ascetoleberis hazardi	5	0.82
32376	Aversovalva fossatum	1	0.16
32376	Bairdoppilata magna	24	3.95
32376	Brachycythere aff. B. foraminosa	39	6.41
32376	Brachycythere ledaforma	16	2.63
32376	Brachycythere ovata	28	4.61
32376	Brachycythere rhomboidalis	48	7.89
32376	Bythocypris windhami	2	0.33
32376	Curfsina communis	7	1.15
32376	"Planileberis" cf. "P." costatana	1	0.16
32376	Cytherella spp.	88	14.47
32376	Cytherelloidea bicosta	17	2.80
32376	Cytheropteron navarroense	1	0.16
32376	Escharacytheridea micro	2	0.33
32376	Escharacytheridea pinochii	2	0.33
32376	Eucythere sohli	2	0.33
32376	Fissocarinocythere huntensis	15	2.47
32376	Haplocytheridea bruceclarki	86	14.14
32376	Krithe whitecliffsensis	3	0.49
32376	Loxoconcha fletcheri	2	0.33
32376	Orthonotacythere hannai	3	0.49
32376	Paracypris sp. 1	1	0.16
32376	Platycosta lixula	8	1.32
32376	Pterygocythere saratogana	5	0.82
32376	Veenia adkinsi	9	1.48
32376	Xestoleberis opina	3	0.49
32376	Xestoleberis seminulata	5	0.82
Total		608	100.00
32390	Amphicytherura curta	17	3.87
32390	Antibythocypris crassa	13	2.96
32390	Antibythocypris fabaformis	10	2.28
32390	Antibythocypris gooberi	54	12.30
32390	Antibythocypris minuta	16	3.64
32390	Antibythocypris multilira	13	2.96
32390	Antibythocypris phaseolites	7	1.59
32390	Anticythereis sp. 7	7	1.59
32390	Anticythereis sp. 15	7	1.59
32390	Anticythereis sp. 16	3	0.68
32390	Bairdoppilata magna	13	2.96

Sample no.	Species	Valves	Percentage
32390	Bairdia w/	14	3.19
32390	Brachycythere aff. B. foraminosa	32	7.29
32390	Brachycythere ovata	49	11.16
32390	Brachycythere rhomboidalis	10	2.28
32390	Curfsina communis	14	3.19
32390	Cushmanidea w/ finely pits	1	0.23
32390	Cushmanidea w/ round pits	10	2.28
32390	"Planileberis" cf. "P." costatana	2	0.46
32390	Cytherella spp.	85	19.36
32390	Cytherelloidea bicosta	12	2.73
32390	Cytheropteron castoensis	4	0.91
32390	Escharacytheridea magnamandibulata	9	2.05
32390	Escharacytheridea pinochii	5	1.14
32390	Fissocarinocythere huntensis	4	0.91
32390	Haplocytheridea bruceclarki	2	0.46
32390	Limburgina foresterae	6	1.37
32390	Loxoconcha erecticosta	2	0.46
32390	Loxoconcha fletcheri	2	0.46
32390	Orthonotacythere hannai	1	0.23
32390	Platycosta lixula	12	2.73
32390	Soudanella parallelopora	1	0.23
32390	Xestoleberis opina	2	0.46
Total		439	100.00
32406	Amphicytherura curta	10	5.52
32406	Antibythocypris crassa	33	18.23
32406	Antibythocypris fabaformis	2	1.10
32406	Antibythocypris gooberi	7	3.87
32406	Antibythocypris phaseolites	2	1.10
32406	Anticythereis sp. 10	5	2.76
32406	Anticythereis sp. 17	4	2.21
32406	Ascetoleberis hazardi	2	1.10
32406	Bairdoppilata magna	29	16.02
32406	Bairdia w/	8	4.42
32406	Brachycythere ovata	17	9.39
32406	Brachycythere rhomboidalis	4	2.21
32406	Bythocypris windhami	5	2.76
32406	Curfsina communis	1	0.55
32406	Cushmanidea w/ round pits	6	3.31
32406	Cytherella spp.	36	19.89
32406	Cytherelloidea crafti	4	2.21
32406	Cytheropteron castoensis	1	0.55
32406	Escharacytheridea magnamandibulata	2	1.10
32406	Limburgina foresterae	3	1.66
Total		181	100.00
32410	Alatacythere aff. A. serrata	7	1.10
32410	Alatacythere ponderosana	3	0.47
32410	Amphicytherura curta	7	1.10
32410	Antibythocypris fabaformis	13	2.03
32410	Antibythocypris gooberi	10	1.56

Sample no.	Species	Valves	Percentage
32410	Argilloecia n. sp. 2	2	0.31
32410	Ascetoleberis hazardi	1	0.16
32410	Brachycythere aff. B. foraminosa	27	4.23
32410	Brachycythere ledaforma	25	3.91
32410	Brachycythere ovata	78	12.21
32410	Brachycythere rhomboidalis	15	2.35
32410	Cuneoceratina aff. C. pedata	3	0.47
32410	Curfsina communis	7	1.10
32410	"Planileberis" cf. "P." costatana	7	1.10
32410	Cytheropteron coryelli	3	0.47
32410	Cytheropteron navarroense	3	0.47
32410	Escharacytheridea pinochii	30	4.69
32410	Fissocarinocythere huntensis	21	3.29
32410	Haplocytheridea bruceclarki	16	2.50
32410	Haplocytheridea everetti	55	8.61
32410	Krithe whitecliffsensis	16	2.50
32410	Macrocypris n. sp.1	2	0.31
32410	Macrocypris n. sp.2	2	0.31
32410	Orthonotacythere hannai	1	0.16
32410	Paracypris sp. 1	1	0.16
32410	Paracypris sp. 4	2	0.31
32410	Platycosta lixula	6	0.94
32410	Pterygocythere saratogana	14	2.19
32410	Veenia adkinsi	21	3.29
32410	Veenia parallelopora	25	3.91
32410	Xestoleberis opina	17	2.66
32410	Bairdoppilata magna	122	19.09
32410	Cytherella spp.	65	10.17
32410	Cytherelloidea bicosta	12	1.88
Total		639	100.00
32412	Amphicytherura curta	1	0.27
32412	Antibythocypris fabaformis	2	0.54
32412	Antibythocypris gooberi	15	4.02
32412	Antibythocypris minuta	2	0.54
32412	Anticythereis sp. 13	1	0.27
32412	Bairdoppilata magna	95	25.47
32412	Brachycythere aff. B. foraminosa	7	1.88
32412	Brachycythere ovata	34	9.12
32412	Brachycythere rhomboidalis	50	13.40
32412	Bythocypris windhami	1	0.27
32412	Curfsina communis	22	5.90
32412	"Planileberis" cf. "P." costatana	1	0.27
32412	Cytherella spp.	35	9.38
32412	Cytheropteron castoensis	5	1.34
32412	Escharacytheridea pinochii	27	7.24
32412	Fissocarinocythere huntensis	6	1.61
32412	Haplocytheridea bruceclarki	1	0.27
32412	Haplocytheridea everetti	17	4.56
32412	Haplocytheridea globosa	17	4.56
32412	Haplocytheridea renfroensis	1	0.27

Sample no.	Species	Valves	Percentage
32412	Haplocytheridea renfroensis (large)	5	1.34
32412	Krithe whitecliffsensis	4	1.07
32412	Limburgina foresterae	8	2.14
32412	Macrocypris n. sp.1	2	0.54
32412	Orthonotacythere hannai	1	0.27
32412	Paracypris sp. 3	2	0.54
32412	Pterygocythere saratogana	3	0.80
32412	Veenia arachoides	4	1.07
32412	Xestoleberis opina	4	1.07
Total		373	100.00
32413	Antibythocypris gooberi	31	7.56
32413	Antibythocypris minuta	1	0.24
32413	Bairdoppilata magna	57	13.90
32413	Brachycythere aff. B. foraminosa	23	5.61
32413	Brachycythere ovata	48	11.71
32413	Brachycythere rhomboidalis	21	5.12
32413	Bythocypris windhami	1	0.24
32413	Curfsina communis	55	13.41
32413	"Planileberis" cf. "P." costatana	9	2.20
32413	Cytherella spp.	38	9.27
32413	Cytherelloidea austinenesis	1	0.24
32413	Cytherelloidea crafti	4	0.98
32413	Cytherelloidea inflata	2	0.49
32413	Cytheropteron castoensis	2	0.49
32413	Escharacytheridea pinochii	14	3.41
32413	Fissocarinocythere huntensis	10	2.44
32413	Fissocarinocythere pidgeoni	2	0.49
32413	Haplocytheridea everetti	49	11.95
32413	Haplocytheridea globosa	23	5.61
32413	Krithe whitecliffsensis	2	0.49
32413	Limburgina foresterae	7	1.71
32413	Macrocypris sp. 1	2	0.49
32413	Orthonotacythere hannai	1	0.24
32413	Pterygocythere saratogana	3	0.73
32413	Veenia arachoides	4	0.98
Total		410	100.00
32414	Amphicytherura curta	13	6.07
32414	Antibythocypris fabaformis	2	0.93
32414	Antibythocypris gooberi	25	11.68
32414	Antibythocypris multilira	1	0.47
32414	Bairdoppilata magna	12	5.61
32414	Brachycythere aff. B. foraminosa	4	1.87
32414	Brachycythere ledaforma	1	0.47
32414	Brachycythere ovata	8	3.74
32414	Brachycythere rhomboidalis	15	7.01
32414	Bythocypris n. sp.1	2	0.93
32414	Curfsina communis	6	2.80
32414	"Planileberis" cf. "P." costatana	3	1.40
32414	Cytherella spp.	25	11.68

Sample no.	Species	Valves	Percentage
32414	Cytherelloidea crafti	4	1.87
32414	Cytheropteron coryelli	1	0.47
32414	Cytheropteron navarroense	1	0.47
32414	Escharacytheridea pinochii	8	3.74
32414	Fissocarinocythere huntensis	1	0.47
32414	Haplocytheridea bruceclarki	18	8.41
32414	Haplocytheridea everetti	37	17.29
32414	Haplocytheridea globosa	14	6.54
32414	Haplocytheridea renfroensis	2	0.93
32414	Krithe whitecliffsensis	4	1.87
32414	Limburgina foresterae	1	0.47
32414	Orthonotacythere hannai	1	0.47
32414	Veenia arachoides	2	0.93
32414	Xestoleberis opina	3	1.40
Total		214	100.00
32416	Alatacythere aff. A. serrata	1	0.51
32416	Alatacythere ponderosana	2	1.03
32416	Antibythocypris fabaformis	1	0.51
32416	Antibythocypris minuta	2	1.03
32416	Ascetoleberis hazardi	2	1.03
32416	Bairdoppilata magna	37	18.97
32416	Brachycythere aff. B. foraminosa	10	5.13
32416	Brachycythere ledaforma	9	4.62
32416	Brachycythere ovata	15	7.69
32416	Brachycythere rhomboidalis	18	9.23
32416	Cuneoceratina aff. C. pedata	1	0.51
32416	Curfsina communis	12	6.15
32416	"Planileberis" cf. "P." costatana	12	6.15
32416	Cytherella spp.	17	8.72
32416	Cytherelloidea austinenesis	1	0.51
32416	Cytherelloidea bicosta	4	2.05
32416	Escharacytheridea pinochii	8	4.10
32416	Fissocarinocythere huntensis	10	5.13
32416	Orthonotacythere hannai	1	0.51
32416	Pterygocythere saratogana	1	0.51
32416	Veenia adkinsi	12	6.15
32416	Veenia parallelopora	15	7.69
32416	Xestoleberis opina	4	2.05
Total		195	100.00
32417	Amphicytherura curta	1	0.45
32417	Antibythocypris fabaformis	2	0.91
32417	Antibythocypris gooberi	4	1.82
32417	Antibythocypris minuta	3	1.36
32417	Antibythocypris pataulensis	1	0.45
32417	Anticythereis sp. 10	2	0.91
32417	Anticythereis sp. 4	3	1.36
32417	Bairdoppilata magna	61	27.73
32417	Bairdia n. sp.	1	0.45
32417	Brachycythere aff. B. foraminosa	11	5.00

Sample no.	Species	Valves	Percentage
32417	Brachycythere ovata	20	9.09
32417	Brachycythere rhomboidalis	13	5.91
32417	Brachycytherecythere n. sp. B	2	0.91
32417	Curfsina communis	18	8.18
32417	"Planileberis" cf. "P." costatana	5	2.27
32417	Cytherella spp.	32	14.55
32417	Cytherelloidea bicosta	9	4.09
32417	Cytherelloidea spiralia	2	0.91
32417	Escharacytheridea pinochii	10	4.55
32417	Haplocytheridea bruceclarki	7	3.18
32417	Haplocytheridea everetti	2	0.91
32417	Krithe whitecliffsensis	1	0.45
32417	Limburgina foresterae	1	0.45
32417	Pterygocythere saratogana	3	1.36
32417	Veenia adkinsi	5	2.27
32417	Xestoleberis opina	1	0.45
Total		220	100.00
32418	Alatacythere aff. A. serrata	2	0.69
32418	Amphicytherura curta	4	1.39
32418	Antibythocypris fabaformis	9	3.13
32418	Antibythocypris gooberi	8	2.78
32418	Antibythocypris minuta	4	1.39
32418	Anticythereis sp. 10	4	1.39
32418	Anticythereis 40	3	1.04
32418	Bairdoppilata magna	67	23.26
32418	Brachycythere leda porosa	21	7.29
32418	Brachycythere ledaforma	1	0.35
32418	Brachycythere ovata	12	4.17
32418	Brachycythere rhomboidalis	7	2.43
32418	Brachycythere n. sp. B	3	1.04
32418	Bythocypris n. sp.3	3	1.04
32418	Curfsina communis	27	9.38
32418	"Planileberis" cf. "P." costatana	2	0.69
32418	Cytherella spp.	44	15.28
32418	Cytherelloidea crafti	11	3.82
32418	Cytherelloidea inflata	2	0.69
32418	Cytheropteron navarroense	1	0.35
32418	Escharacytheridea pinochii	15	5.21
32418	Fissocarinocythere huntensis	3	1.04
32418	Haplocytheridea bruceclarki	12	4.17
32418	Haplocytheridea everetti	3	1.04
32418	Haplocytheridea globosa	1	0.35
32418	Haplocytheridea renfroensis	1	0.35
32418	Limburgina foresterae	2	0.69
32418	Pterygocythere saratogana	2	0.69
32418	Veenia arachoides	14	4.86
Total		288	100.00
32419	Amphicytherura curta	13	2.72
32419	Antibythocypris crassa	5	1.05

Sample no.	Species	Valves	Percentage
32419	Antibythocypris fabaformis	3	0.63
32419	Antibythocypris gooberi	47	9.83
32419	Antibythocypris minuta	15	3.14
32419	Anticythereis sp. 10	3	0.63
32419	Anticythereis sp. 13	2	0.42
32419	Argilloecia n. sp. 1	2	0.42
32419	Bairdoppilata magna	52	10.88
32419	Brachycythere aff. B. foraminosa	19	3.97
32419	Brachycythere ledaforma	1	0.21
32419	Brachycythere ovata	31	6.49
32419	Brachycythere rhomboidalis	14	2.93
32419	Brachycythere n. sp. B	1	0.21
32419	Bythocypris n. sp.3	4	0.84
32419	Curfsina communis	52	10.88
32419	"Planileberis" cf. "P." costatana	5	1.05
32419	Cytherella spp.	47	9.83
32419	Cytherelloidea austinenesis	8	1.67
32419	Cytherelloidea crafti	14	2.93
32419	Cytherelloidea inflata	2	0.42
32419	Cytheropteron castoensis	5	1.05
32419	Escharacytheridea pinochii	29	6.07
32419	Fissocarinocythere huntensis	14	2.93
32419	Fissocarinocythere pidgeoni	1	0.21
32419	Haplocytheridea bruceclarki	16	3.35
32419	Haplocytheridea everetti	17	3.56
32419	Haplocytheridea globosa	10	2.09
32419	Haplocytheridea renfroensis	7	1.46
32419	Krithe whitecliffsensis	1	0.21
32419	Limburgina foresterae	14	2.93
32419	Pterygocythere saratogana	5	1.05
32419	Sphaeroleberis pseudo	1	0.21
32419	Veenia arachoides	8	1.67
32419	Xestoleberis n. sp. 2	2	0.42
32419	Xestoleberis opina	8	1.67
Total		478	100.00
32880	Alatacythere ponderosana	2	2.15
32880	Argilloecia n. sp. 1	2	2.15
32880	Bairdoppilata magna	11	11.83
32880	Brachycythere aff. B. foraminosa	4	4.30
32880	Brachycythere ovata	6	6.45
32880	Brachycythere rhomboidalis	2	2.15
32880	Curfsina communis	4	4.30
32880	Cytherella spp.	18	19.35
32880	Cytherelloidea bicosta	9	9.68
32880	Haplocytheridea bruceclarki	11	11.83
32880	Haplocytheridea everetti	0	0.00
32880	Krithe whitecliffsensis	2	2.15
32880	Pterygocythere saratogana	1	1.08
32880	Xestoleberis opina	17	18.28

Sample no.	Species	Valves	Percentage
32880	Xestoleberis seminulata	4	4.30
Total		93	100.00
32891	Alatacythere ponderosana	1	2.94
32891	Bairdoppilata magna	6	17.65
32891	Brachycythere ovata	1	2.94
32891	Brachycythere rhomboidalis	2	5.88
32891	"Planileberis" cf. "P." costatana	1	2.94
32891	Cytherella spp.	2	5.88
32891	Haplocytheridea bruceclarki	4	11.76
32891	Krithe whitecliffsensis	1	2.94
32891	Platycosta lixula	1	2.94
32891	Veenia parallelopora	14	41.18
32891	Xestoleberis opina	1	2.94
Total		34	100.00
32936	Amphicytherura curta	1	0.24
32936	Antibythocypris gooberi	17	4.12
32936	Argilloecia n. sp. 1	4	0.97
32936	Ascetoleberis hazardi	1	0.24
32936	Bairdia w/	2	0.48
32936	Brachycythere aff. B. foraminosa	4	0.97
32936	Brachycythere ovata	75	18.16
32936	Brachycythere rhomboidalis	58	14.04
32936	Bythocypris windhami	5	1.21
32936	Curfsina communis	5	1.21
32936	Cytherella spp.	47	11.38
32936	Escharacytheridea magnamandibulata	2	0.48
32936	Escharacytheridea micropunctata	3	0.73
32936	Haplocytheridea everetti	48	11.62
32936	Haplocytheridea renfroensis	113	27.36
32936	Krithe whitecliffsensis	3	0.73
32936	Loxoconcha cretacea	18	4.36
32936	Loxoconcha plegma	1	0.24
32936	Macrocypris sp. 1	2	0.48
32936	Xestoleberis seminulata	4	0.97
Total		413	100.00
33208	Amphicytherura curta	2	0.50
33208	Antibythocypris gooberi	18	4.46
33208	Ascetoleberis hazardi	1	0.25
33208	Bairdoppilata magna	1	0.25
33208	Bairdia n. sp.1	1	0.25
33208	Brachycythere aff. B. foraminosa	5	1.24
33208	Brachycythere ovata	69	17.08
33208	Brachycythere rhomboidalis	38	9.41
33208	Bythocypris windhami	3	0.74
33208	Curfsina communis	14	3.47
33208	Cytherella spp.	65	16.09
33208	Escharacytheridea magnamandibulata	2	0.50
33208	Escharacytheridea pinochii	1	0.25

Sample no.	Species	Valves	Percentage
33208	Haplocytheridea everetti	69	17.08
33208	Haplocytheridea renfroensis	107	26.49
33208	Loxoconcha clinocosta	1	0.25
33208	Loxoconcha cretacea	5	1.24
33208	Orthonotacythere hannai	1	0.25
33208	Xestoleberis seminulata	1	0.25
Total		404	100.00
33209	Brachycythere aff. B. foraminosa	1	0.07
33209	Brachycythere ovata	71	5.21
33209	Brachycythere rhomboidalis	75	5.50
33209	Cytherella spp.	224	16.43
33209	Cytherelloidea aff. tolletensis	4	0.29
33209	Haplocytheridea everetti	76	5.58
33209	Haplocytheridea renfroensis	544	39.91
33209	Antibythocypris fabaformis	13	0.95
33209	Antibythocypris gooberi	15	1.10
33209	Antibythocypris minuta	42	3.08
33209	Anticythereis 41	2	0.15
33209	Bairdia w/	9	0.66
33209	Curfsina communis	1	0.07
33209	Cushmanidea w/ pits& grooves	6	0.44
33209	Cushmanidea w/ round pits	1	0.07
33209	Cytheromorpha cf. C. pittsi	10	0.73
33209	Fissocarinocythere pidgeoni	11	0.81
33209	Krithe whitecliffsensis	4	0.29
33209	Limburgina foresterae	2	0.15
33209	Loxoconcha clinocosta	17	1.25
33209	Loxoconcha cretacea	136	9.98
33209	Loxoconcha erecticosta	35	2.57
33209	Orthonotacythere hannai	14	1.03
33209	Platycosta lixula	11	0.81
33209	Polylophus asper	2	0.15
33209	Soudanella parallelopora	2	0.15
33209	Xestoleberis n. sp. 4	8	0.59
33209	Xestoleberis opina	6	0.44
33209	Xestoleberis seminulata	21	1.54
Total		1363	100.00
33212	Amphicytherura curta	1	0.24
33212	Antibythocypris crassa	4	0.96
33212	Antibythocypris elongata	13	3.12
33212	Antibythocypris fabaformis	2	0.48
33212	Antibythocypris gooberi	1	0.24
33212	Antibythocypris minuta	3	0.72
33212	Antibythocypris multilira	33	7.91
33212	Antibythocypris phaseolites	7	1.68
33212	Anticythereis sp. 6	3	0.72
33212	Anticythereis 8	1	0.24
33212	Anticythereis copelandi	1	0.24
33212	Brachycythere aff. B. foraminosa	27	6.47

Sample no.	Species	Valves	Percentage
33212	Brachycythere ovata	45	10.79
33212	Curfsina communis w/ pits	4	0.96
33212	Cytheromorpha cf. C. arbenzi	2	0.48
33212	Cytheropteron castorensis	2	0.48
33212	Fissocarinocythere pidgeoni	5	1.20
33212	Haplocytheridea everetti	32	7.67
33212	Haplocytheridea globosa	24	5.76
33212	Loxoconcha clinocosta	56	13.43
33212	Loxoconcha erecticosta	7	1.68
33212	Loxoconcha minardi	2	0.48
33212	Platycosta lixula	19	4.56
33212	Polylophus asper	2	0.48
33212	Soudanella n. sp. B	2	0.48
33212	Soudanella parallelopora	10	2.40
33212	Cytherella spp.	89	21.34
33212	Krithe whitecliffsensis	15	3.60
33212	Xestoleberis n. sp. 4	5	1.20
Total		417	100.00
33213	Amphicytherura curta	7	3.07
33213	Antibythocypris crassa	6	2.63
33213	Antibythocypris fabaformis	8	3.51
33213	Antibythocypris macropora	3	1.32
33213	Antibythocypris minuta	5	2.19
33213	Antibythocypris multilira	15	6.58
33213	Antibythocypris phaseolites	7	3.07
33213	Anticythereis sp. 6	3	1.32
33213	Anticythereis copelandi	2	0.88
33213	Argilloecia n. sp. 1	4	1.75
33213	Aversovalva fossatum	3	1.32
33213	Brachycythere aff. B. foraminosa	2	0.88
33213	Brachycythere ovata	6	2.63
33213	Brachycythere rhomboidalis	3	1.32
33213	Cushmanidea sp.	2	0.88
33213	Cytherella spp.	45	19.74
33213	Eocytheropteron striatum	12	5.26
33213	Fissocarinocythere pidgeoni	2	0.88
33213	Haplocytheridea everetti	10	4.39
33213	Haplocytheridea globosa	12	5.26
33213	Loxoconcha clinocosta	32	14.04
33213	Loxoconcha erecticosta	17	7.46
33213	Loxoconcha n. sp. B	6	2.63
33213	Loxoconcha striata	2	0.88
33213	Platycosta lixula	5	2.19
33213	Polylophus asper	6	2.63
33213	Soudanella parallelopora	3	1.32
Total		228	100.00
33214	Amphicytherura curta	2	2.06
33214	Antibythocypris crassa	1	1.03
33214	Antibythocypris fabaformis	4	4.12

Sample no.	Species	Valves	Percentage
33214	Antibythocypris multilira	1	1.03
33214	Antibythocypris phaseolites	4	4.12
33214	Anticythereis sp. 6	2	2.06
33214	Bairdoppilata magna	2	2.06
33214	Brachycythere aff. B. foraminosa	4	4.12
33214	Brachycythere ovata	7	7.22
33214	Brachycythere rhomboidalis	3	3.09
33214	Cushmanidea w/ pits	2	2.06
33214	Cytherella spp.	34	35.05
33214	Cytherelloidea bicosta	1	1.03
33214	Fissocarinocythere pidgeoni	1	1.03
33214	Haplocytheridea everetti	3	3.09
33214	Haplocytheridea globosa	2	2.06
33214	Krithe whitecliffsensis	6	6.19
33214	Loxoconcha clinocosta	8	8.25
33214	Loxoconcha n. sp. B	1	1.03
33214	Platycosta lixula	2	2.06
33214	Xestoleberis opina	5	5.15
33214	Xestoleberis seminulata	2	2.06
Total		97	100.00
33223	Amphicytherura curta	2	1.45
33223	Antibythocypris crassa	3	2.17
33223	Antibythocypris fabaformis	15	10.87
33223	Antibythocypris minuta	1	0.72
33223	Antibythocypris multilira	1	0.72
33223	Antibythocypris pataulensis	1	0.72
33223	Anticythereis sp. 10	1	0.72
33223	Ascetoleberis hazardi	1	0.72
33223	Bairdia n. sp.1	3	2.17
33223	Brachycythere aff. B. foraminosa	4	2.90
33223	Brachycythere ovata	58	42.03
33223	Brachycythere rhomboidalis	3	2.17
33223	Brachycythere rhomboidalis w/ ridge	2	1.45
33223	Cytherella spp.	39	28.26
33223	Escharacytheridea pinochii	1	0.72
33223	Haplocytheridea renfroensis	1	0.72
33223	Xestoleberis seminulata	2	1.45
Total		138	100.00
33229	Amphicytherura curta	6	1.83
33229	Antibythocypris crassa	2	0.61
33229	Antibythocypris fabaformis	4	1.22
33229	Antibythocypris gooberi	45	13.72
33229	Antibythocypris minuta	4	1.22
33229	Anticythereis sp. 4	5	1.52
33229	Ascetoleberis hazardi	9	2.74
33229	Bairdoppilata magna	45	13.72
33229	Brachycythere aff. B. foraminosa	17	5.18
33229	Brachycythere ovata	19	5.79
33229	Brachycythere rhomboidalis	37	11.28

Sample no.	Species	Valves	Percentage
33229	Bythocypris windhami	1	0.30
33229	Curfsina communis	26	7.93
33229	"Planileberis" cf. "P." costatana	4	1.22
33229	Cytherella spp.	43	13.11
33229	Cytherelloidea austinenesis	7	2.13
33229	Cytherelloidea crafti	5	1.52
33229	Cytherelloidea inflata	2	0.61
33229	Cytheropteron castoensis	1	0.30
33229	Cytheropteron navarroense	3	0.91
33229	Escharacytheridea pinochii	6	1.83
33229	Eucythere sohli	2	0.61
33229	Fissocarinocythere huntensis	3	0.91
33229	Haplocytheridea bruceclarki	2	0.61
33229	Haplocytheridea everetti	8	2.44
33229	Haplocytheridea renfroensis (large)	2	0.61
33229	Krithe whitecliffsensis	2	0.61
33229	Monoceratina n. sp. C	2	0.61
33229	Platycosta lixula	2	0.61
33229	Pterygocythere saratogana	1	0.30
33229	Veenia arachoides	6	1.83
33229	Xestoleberis opina	7	2.13
Total		328	100.00
33233	Amphicytherura curta	2	1.59
33233	Antibythocypris gooberi	1	0.79
33233	Argilloecia n. sp. 1	2	1.59
33233	Bairdoppilata magna	1	0.79
33233	Brachycythere ovata	9	7.14
33233	Brachycythere rhomboidalis	1	0.79
33233	Curfsina communis	1	0.79
33233	Cytherella spp.	49	38.89
33233	Cytherelloidea bicosta	1	0.79
33233	Haplocytheridea everetti	9	7.14
33233	Haplocytheridea globosa	14	11.11
33233	Krithe whitecliffsensis	12	9.52
33233	Loxoconcha clinocosta	5	3.97
33233	Loxoconcha erecticosta	7	5.56
33233	Platycosta lixula	1	0.79
33233	Polylophus asper	3	2.38
33233	Soudanella parallelopora	2	1.59
33233	Xestoleberis seminulata	6	4.76
Total		126	100.00
33234	Amphicytherura curta	7	1.19
33234	Antibythocypris fabaformis	1	0.17
33234	Antibythocypris gooberi	4	0.68
33234	Antibythocypris multilira	1	0.17
33234	Anticythereis sp. 6	1	0.17
33234	Anticythereis sp. 3	3	0.51
33234	Argilloecia n. sp. 1	2	0.34
33234	Bairdoppilata magna	2	0.34

Sample no.	Species	Valves	Percentage
33234	Bairdia w/	1	0.17
33234	Brachycythere aff. B. foraminosa	27	4.58
33234	Brachycythere ovata	29	4.92
33234	Brachycythere rhomboidalis	4	0.68
33234	Curfsina communis var.	3	0.51
33234	Cushmanidea w/ round pits	4	0.68
33234	"Planileberis" cf. "P." costatana	2	0.34
33234	Cytherella spp.	134	22.71
33234	Cytherelloidea aff. tolletensis	2	0.34
33234	Cytherelloidea spiralia	5	0.85
33234	Cytheromorpha cf. c. arbenzi	10	1.69
33234	Cytheromorpha cf. C. pittsi	6	1.02
33234	Cytheromorpha n. sp. A	6	1.02
33234	Fissocarinocythere pidgeoni	1	0.17
33234	Haplocytheridea bruceclarki	2	0.34
33234	Haplocytheridea everetti	64	10.85
33234	Haplocytheridea globosa	77	13.05
33234	Krithe whitecliffsensis	22	3.73
33234	Loxoconcha clinocosta	46	7.80
33234	Loxoconcha cretacea	1	0.17
33234	Loxoconcha erecticosta	50	8.47
33234	Loxoconcha nuda?	2	0.34
33234	Loxoconcha striata	11	1.86
33234	Platycosta lixula	28	4.75
33234	Polylophus asper	7	1.19
33234	Soudanella parallelopora	2	0.34
33234	Xestoleberis seminulata	23	3.90
Total		590	100.00
33236	Antibythocypris fabaformis	3	0.45
33236	Antibythocypris gooberi	15	2.23
33236	Anticythereis sp. 4	1	0.15
33236	Ascetoleberis hazardi	42	6.23
33236	Bairdoppilata magna	30	4.45
33236	Brachycythere aff. B. foraminosa	5	0.74
33236	Brachycythere ledaforma	6	0.89
33236	Brachycythere ovata	126	18.69
33236	Brachycythere rhomboidalis	49	7.27
33236	Curfsina communis	39	5.79
33236	Cytherella spp.	212	31.45
33236	Cytheropteron coryelli	1	0.15
33236	Haplocytheridea everetti	45	6.68
33236	Haplocytheridea globosa	31	4.60
33236	Krithe whitecliffsensis	42	6.23
33236	Limburgina foresterae	5	0.74
33236	Loxoconcha clinocosta	6	0.89
33236	Loxoconcha striata	1	0.15
33236	Orthonotacythere hannai	5	0.74
33236	Platycosta lixula	1	0.15
33236	Pterygocythere saratogana	1	0.15
33236	Soudanella parallelopora	1	0.15

Sample no.	Species	Valves	Percentage
33236	Xestoleberis opina	2	0.30
33236	Xestoleberis seminulata	5	0.74
Total		674	100.00
33239	Cytherella spp.	43	16.48
33239	Antibythocypris gooberi	8	3.07
33239	Brachycythere foraminosa s.l.	10	3.83
33239	Brachycythere ledaforma	2	0.77
33239	Brachycythere ovata	29	11.11
33239	Brachycythere rhomboidalis	26	9.96
33239	Bairdoppilata mag	15	5.75
33239	Curfsina communis	8	3.07
33239	Cytherella	38	14.56
33239	Cytherelloidea bicosta s.l.	7	2.68
33239	Escharacytheridea micropunctata	18	6.90
33239	Fissocarinocythere huntensis	1	0.38
33239	Haplocytheridea everetti	29	11.11
33239	Haplocytheridea bruceclarki	16	6.13
33239	Haplocytheridea renfroensis	4	1.53
33239	"Planileberis" cf. "P." costatana	1	0.38
33239	Pterygocythere saratogana	2	0.77
33239	Xestoleberis opina	4	1.53
Total		261	100.00
33240	Bairdoppilata magna	16	6.56
33240	Brachy foraminosa	7	2.87
33240	Brachy ledaforma	7	2.87
33240	Brachy ovata	34	13.93
33240	Brachy rhomboidalis	51	20.90
33240	Curfsina communis	8	3.28
33240	Cytherella spp.	56	22.95
33240	Cytherelloidea aff. spiralia	2	0.82
33240	Cytherelloidea bicosta	2	0.82
33240	Escharacytheridea micropunctata	9	3.69
33240	Haplocytheridea everetti	20	8.20
33240	Haplocytheridea renfroensis	9	3.69
33240	Krithe whitecliffsensis	10	4.10
33240	Loxoconcha erecticosta	1	0.41
33240	Platycosta lixula	1	0.41
33240	Xestoleberis seminulata	11	4.51
Total		244	100.00
33243	Amphicytherura curta	22	7.36
33243	Antibythocypris crassa	3	1.00
33243	Antibythocypris fabaformis	11	3.68
33243	Antibythocypris gooberi	6	2.01
33243	Antibythocypris minuta	2	0.67
33243	Antibythocypris pataulensis	5	1.67
33243	Anticythereis sp. 11	1	0.33
33243	Anticythereis sp. 17	1	0.33
33243	Anticythereis copelandi	1	0.33

Sample no.	Species	Valves	Percentage
33243	Bairdia n. sp.1	12	4.01
33243	Bairdia n. sp.2	10	3.34
33243	Brachy aff. B. foraminosa	9	3.01
33243	Brachy ovata	63	21.07
33243	Brachy rhomboidalis	23	7.69
33243	Curfsina communis w/ pits	15	5.02
33243	Cytherella spp.	73	24.41
33243	Cytherelloidea bicosta	2	0.67
33243	Escharacytheridea magnamandibulata	2	0.67
33243	Genus? 5	2	0.67
33243	Haplocytheridea everetti	3	1.00
33243	Haplocytheridea renfroensis	11	3.68
33243	Loxoconcha striata	4	1.34
33243	Macrocypris sp. 1	2	0.67
33243	Paracypris sp. 4	6	2.01
33243	Platycosta lixula	2	0.67
33243	Pterygocythere saratogana	1	0.33
33243	Xestoleberis opina	1	0.33
33243	Xestoleberis seminulata	6	2.01
Total		299	100.00
33248	Antibythocypris elongata	2	6.67
33248	Antibythocypris fabaformis	6	20.00
33248	Brachy aff. B. leda porosa	3	10.00
33248	Brachy ovata	2	6.67
33248	Cytherella spp.	10	33.33
33248	Escharacytheridea micropunctata	5	16.67
33248	Paracypris sp. 1	2	6.67
Total		30	100.00
CS-ALA-74-1-H	Acantocythereis washingtonensis	58	23.11
CS-ALA-74-1-H	Brachycythere ovata w/ ridge	9	3.59
CS-ALA-74-1-H	Brachycythere plena	41	16.33
CS-ALA-74-1-H	Bairdoppilata magna	6	2.39
CS-ALA-74-1-H	Cytherella	22	8.76
CS-ALA-74-1-H	Cytherelloidea sullivani	1	0.40
CS-ALA-74-1-H	Cytherelloidea truncata lowndesensis	2	0.80
CS-ALA-74-1-H	Hermanites gibsoni	16	6.37
CS-ALA-74-1-H	Orthonotacythere cristata	8	3.19
CS-ALA-74-1-H	Ouachitaia aff. O. ruida	1	0.40
CS-ALA-74-1-H	Paracypris perapiculata	3	1.20
CS-ALA-74-1-H	Phractocytheridea ruginosa	61	24.30
CS-ALA-74-1-H	Haplocytheridea fornicata	23	9.16
Total		251	100.00
CS-ALA-74-1-I	Acantocythereis washingtonensis	90	16.01
CS-ALA-74-1-I	Brachycythere plena	205	36.48
CS-ALA-74-1-I	Bairdoppilata magna	3	0.53
CS-ALA-74-1-I	Cytherella	32	5.69
CS-ALA-74-1-I	Cytherelloidea sullivani	3	0.53

Sample no.	Species	Valves	Percentage
CS-ALA-74-1-I	Hermanites gibsoni	80	14.23
CS-ALA-74-1-I	Orthonotacythere cristata	31	5.52
CS-ALA-74-1-I	Paracypris perapiculata	3	0.53
CS-ALA-74-1-I	Phractocytheridea ruginosa	67	11.92
CS-ALA-74-1-I	Haplocytheridea fornicata	48	8.54
Total		562	100.00
CS-ALA-74-1-J	Acantocythereis washingtonensis	44	10.33
CS-ALA-74-1-J	Brachycythere plena	80	18.78
CS-ALA-74-1-J	Bairdoppilata magna	10	2.35
CS-ALA-74-1-J	Cytherella	52	12.21
CS-ALA-74-1-J	Cytherelloidea truncata lowndesensis	1	0.23
CS-ALA-74-1-J	Cytheromorpha braggsensis	29	6.81
CS-ALA-74-1-J	Cytheromorpha pittsi	9	2.11
CS-ALA-74-1-J	Hermanites gibsoni	22	5.16
CS-ALA-74-1-J	Loxoconcha alantica	3	0.70
CS-ALA-74-1-J	Loxoconcha nuda	1	0.23
CS-ALA-74-1-J	Orthonotacythere cristata	19	4.46
CS-ALA-74-1-J	Phractocytheridea ruginosa	22	5.16
CS-ALA-74-1-J	Haplocytheridea fornicata	134	31.46
Total		426	100.00
CS-ALA-74-1-K	Acantocythereis washingtonensis	26	5.83
CS-ALA-74-1-K	Brachycythere plena	18	4.04
CS-ALA-74-1-K	Clithrocytheridea n. sp. A	4	0.90
CS-ALA-74-1-K	Cytherella	8	1.79
CS-ALA-74-1-K	Cytherelloidea sullivani	3	0.67
CS-ALA-74-1-K	Cytherelloidea truncata lowndesensis	8	1.79
CS-ALA-74-1-K	Hermanites gibsoni	68	15.25
CS-ALA-74-1-K	Orthonotacythere cristata	70	15.70
CS-ALA-74-1-K	Opimocythere n. sp.A	20	4.48
CS-ALA-74-1-K	Ouachi aff. ruida	1	0.22
CS-ALA-74-1-K	Paracypris perapiculata	1	0.22
CS-ALA-74-1-K	Phractocytheridea ruginosa	67	15.02
CS-ALA-74-1-K	Haplocytheridea fornicata	152	34.08
Total		446	100.00
CS-ALA-74-1-L	Acantocythereis washingtonensis	47	26.40
CS-ALA-74-1-L	Brachycythere plena	37	20.79
CS-ALA-74-1-L	Cytherella	46	25.84
CS-ALA-74-1-L	Cytherelloidea sullivani	1	0.56
CS-ALA-74-1-L	Hermanites n. sp. A	2	1.12
CS-ALA-74-1-L	Orthonotacythere cristata	25	14.04
CS-ALA-74-1-L	Haplocytheridea fornicata	20	11.24
Total		178	100.00
HVH 453C	Brachycythere ovata	1	1.72
HVH 453C	Brachycythere rhomboidalis	1	1.72
HVH 453C	Bairdoppilata magna	5	8.62
HVH 453C	Curfsina communis	1	1.72
HVH 453C	Cytherella	8	13.79

Sample no.	Species	Valves	Percentage
HVH 453C	Cytherelloidea bicosta s.l.	6	10.34
HVH 453C	Haplocytheridea bruceclarki	15	25.86
HVH 453C	Haplocytheridea everetti	10	17.24
HVH 453C	"Planileberis" cf. "P." costatana	1	1.72
HVH 453C	Veenia parallelopora	2	3.45
HVH 453C	Xestoleberis opina	6	10.34
HVH 453C	Xestoleberis seminulata	2	3.45
Total		58	100.00
KP-2-91-I-1	Alatacythere aff. A. serrata	6	1.43
KP-2-91-I-1	Ascetoleberis hazardi	22	5.23
KP-2-91-I-1	Brachycythere foraminosa	3	0.71
KP-2-91-I-1	Brachycythere ledaforma	5	1.19
KP-2-91-I-1	Brachycythere ovata	82	19.48
KP-2-91-I-1	Brachycythere rhomboidalis	76	18.05
KP-2-91-I-1	Curfsina communis	20	4.75
KP-2-91-I-1	Cytherella	119	28.27
KP-2-91-I-1	Cytheropteron navarroense	7	1.66
KP-2-91-I-1	Escharacytheridea micropunctata	1	0.24
KP-2-91-I-1	Eucythere sohli	1	0.24
KP-2-91-I-1	Fissocarinocythere huntensis	11	2.61
KP-2-91-I-1	Haplocytheridea bruceclarki	40	9.50
KP-2-91-I-1	Krithe whitecliffsensis	19	4.51
KP-2-91-I-1	Loxoconcha clinocosta	1	0.24
KP-2-91-I-1	Loxoconcha striata	1	0.24
KP-2-91-I-1	"Monoceratina" aff. umbonata	1	0.24
KP-2-91-I-1	"Monoceratina" n. sp. C	2	0.48
KP-2-91-I-1	Pterygocythere saratogana	4	0.95
Total		421	100.00
KP-2-91-I-3	Antibythocypris crassa	1	2.78
KP-2-91-I-3	Brachycythere ovata	5	13.89
KP-2-91-I-3	Brachycythere ovata w/ ridge	3	8.33
KP-2-91-I-3	Bairdoppilata magna	22	61.11
KP-2-91-I-3	Cytherella	4	11.11
KP-2-91-I-3	Haplocytheridea everetti	1	2.78
Total		36	100.00
KP-2-91-I-4	Alatacythere aff. A. serrata	19	6.01
KP-2-91-I-4	Ascetoleberis hazardi	13	4.11
KP-2-91-I-4	Brachycythere foraminosa	5	1.58
KP-2-91-I-4	Brachycythere ledaforma	15	4.75
KP-2-91-I-4	Brachycythere ovata	35	11.08
KP-2-91-I-4	Brachycythere rhomboidalism	29	9.18
KP-2-91-I-4	Bairdoppilata magna	2	0.63
KP-2-91-I-4	Curfsina communis	19	6.01
KP-2-91-I-4	Cytherella	82	25.95
KP-2-91-I-4	Cytheropteron navarroense	4	1.27
KP-2-91-I-4	Escharacytheridea micropunctata	8	2.53
KP-2-91-I-4	Haplocytheridea bruceclarki	44	13.92
KP-2-91-I-4	Krithe whitecliffsensis	24	7.59

Sample no.	Species	Valves	Percentage
KP-2-91-I-4	Loxoconcha striata	2	0.63
KP-2-91-I-4	Paracypris sp. 3	2	0.63
KP-2-91-I-4	Pterygocythere saratogana	13	4.11
Total		316	100.00
KP-2-91-I-5	Acantocythereis washingtonensis	24	4.31
KP-2-91-I-5	Alatacythere lemincuta	5	0.90
KP-2-91-I-5	Brachycythere plena	102	18.31
KP-2-91-I-5	Bairdoppilata magna	132	23.70
KP-2-91-I-5	Cytherella	116	20.83
KP-2-91-I-5	Hazelina sp. A	30	5.39
KP-2-91-I-5	Krithe n. sp. B	9	1.62
KP-2-91-I-5	Loxoconcha corrugata	5	0.90
KP-2-91-I-5	Loxoconcha n. sp. A	3	0.54
KP-2-91-I-5	Loxoconcha n. sp. C (Tertiary)	4	0.72
KP-2-91-I-5	Loxoconcha n. sp. D (Tertiary)	1	0.18
KP-2-91-I-5	Paracypris sp. 3	5	0.90
KP-2-91-I-5	Phacorhabdotus aff. P. formosus	95	17.06
KP-2-91-I-5	Phacorhabdotus formosa	13	2.33
KP-2-91-I-5	Phacorhabdotus sculptilis	11	1.97
KP-2-91-I-5	Xestoleberis seminulata	2	0.36
Total		557	100.00
KP-2-91-II-3	Amphicytherura curta	1	1.14
KP-2-91-II-3	Antibythocypris crassa	2	2.27
KP-2-91-II-3	Antibythocypris minuta	5	5.68
KP-2-91-II-3	Brachycythere ovata	10	11.36
KP-2-91-II-3	Brachycythere ovata w/	1	1.14
KP-2-91-II-3	Bairdoppilata magna	25	28.41
KP-2-91-II-3	Bythocypris windhami	2	2.27
KP-2-91-II-3	Curfsina communis	5	5.68
KP-2-91-II-3	Cytherella	35	39.77
KP-2-91-II-3	Xestoleberis opina	2	2.27
Total		88	100.00
KP-2-91-II-4	Amphicytherura curta	26	10.04
KP-2-91-II-4	Antibythocypris crassa	8	3.09
KP-2-91-II-4	Antibythocypris fabaformis	5	1.93
KP-2-91-II-4	Antibythocypris gooberi	24	9.27
KP-2-91-II-4	Antibythocypris minuta	14	5.41
KP-2-91-II-4	Antibythocypris pataulensis	5	1.93
KP-2-91-II-4	Anticythereis sp. 4	4	1.54
KP-2-91-II-4	Anticythereis sp. 14	3	1.16
KP-2-91-II-4	Ascetoleberis hazardi	1	0.39
KP-2-91-II-4	Brachycythere foraminosa	8	3.09
KP-2-91-II-4	Brachycythere ovata	10	3.86
KP-2-91-II-4	Brachycythere rhomboidalis	4	1.54
KP-2-91-II-4	Bairdoppilata magna	67	25.87
KP-2-91-II-4	Bairdia w/ denticulation	4	1.54
KP-2-91-II-4	Curfsina communis	36	13.90
KP-2-91-II-4	"Planileberis" cf. "P." costatana	3	1.16

Sample no.	Species	Valves	Percentage
KP-2-91-II-4	Cytheropteron navarroense	3	1.16
KP-2-91-II-4	Cytherelloidea bicosta	4	1.54
KP-2-91-II-4	Cytherella	17	6.56
KP-2-91-II-4	Cytherelloidea aff. C. austinensis	5	1.93
KP-2-91-II-4	Escharacytheridea pinochii	2	0.77
KP-2-91-II-4	Fissocarinocythere huntensis	4	1.54
KP-2-91-II-4	Haplocytheridea bruceclarki	4	1.54
KP-2-91-II-4	Haplocytheridea everetti	9	3.47
KP-2-91-II-4	Limburgina foresterae	5	1.93
KP-2-91-II-4	Veenia adkinsi	10	3.86
KP-2-91-II-4	Xestoleberis opina	4	1.54
Total		259	100.00
KP-2-91-III-1	Alatacythere aff. A. serrata	20	1.52
KP-2-91-III-1	Amphicytherura curta	69	5.24
KP-2-91-III-1	Antibythocypris crassa	2	0.15
KP-2-91-III-1	Antibythocypris gooberi	38	2.89
KP-2-91-III-1	Antibythocypris minuta	5	0.38
KP-2-91-III-1	Antibythocypris trisulcata	3	0.23
KP-2-91-III-1	Anticythereis sp. 14	3	0.23
KP-2-91-III-1	Anticythereis sp. 17	6	0.46
KP-2-91-III-1	Anticythereis sp. 4	2	0.15
KP-2-91-III-1	Argilloecia n sp 1	1	0.08
KP-2-91-III-1	Argilloecia n sp 2	2	0.15
KP-2-91-III-1	Aversovalva fossata s.l.	12	0.91
KP-2-91-III-1	Brachycythere foraminosa s.l.	156	11.85
KP-2-91-III-1	Brachycythere ledaforma	29	2.20
KP-2-91-III-1	Brachycythere ovata	101	7.67
KP-2-91-III-1	Brachycythere ovata w/	3	0.23
KP-2-91-III-1	Brachycythere rhomboidalis	40	3.04
KP-2-91-III-1	Bairdoppilata magna	124	9.42
KP-2-91-III-1	Bairdia w/ denticulation	10	0.76
KP-2-91-III-1	Bythocypris windhami	8	0.61
KP-2-91-III-1	Curfsina communis	60	4.56
KP-2-91-III-1	Cushman w/ round pits	3	0.23
KP-2-91-III-1	Cytherella	212	16.11
KP-2-91-III-1	Cytherelloidea bicosta s.l.	45	3.42
KP-2-91-III-1	Cytheropteron castorensis	1	0.08
KP-2-91-III-1	Cytheropteron cf. type A	4	0.30
KP-2-91-III-1	Cytheropteron coryelli	2	0.15
KP-2-91-III-1	Escharacytheridea pinochii	45	3.42
KP-2-91-III-1	Eucythere sohli	4	0.30
KP-2-91-III-1	Eucytherura aff. E. reticulata	10	0.76
KP-2-91-III-1	Fissocarinocythere huntensis	18	1.37
KP-2-91-III-1	Haplocytheridea bruceclarki	20	1.52
KP-2-91-III-1	Krithe whitecliffsensis	60	4.56
KP-2-91-III-1	Limburgina foresterae	25	1.90
KP-2-91-III-1	Loxoconcha clinocosta	3	0.23
KP-2-91-III-1	Loxoconcha fletcheri	2	0.15
KP-2-91-III-1	Loxoconcha striata	5	0.38
KP-2-91-III-1	Macrocypris n. sp. 3	2	0.15

Sample no.	Species	Valves	Percentage
KP-2-91-III-1	Bythoceratina aff. B. acanthoptera	2	0.15
KP-2-91-III-1	"Monoceratina" n. sp. E	2	0.15
KP-2-91-III-1	Orthonotacythere hannai	6	0.46
KP-2-91-III-1	Paracypris sp. 3	3	0.23
KP-2-91-III-1	"Planileberis" cf. "P." costatana	5	0.38
KP-2-91-III-1	Platycosta lixula	27	2.05
KP-2-91-III-1	Polylophus asper	3	0.23
KP-2-91-III-1	Pterygocythere saratogana	8	0.61
KP-2-91-III-1	Veenia parallelopora	4	0.30
KP-2-91-III-1	Veenia adkinsi	5	0.38
KP-2-91-III-1	Xestoleberis n. sp. 3	2	0.15
KP-2-91-III-1	Xestoleberis opina	94	7.14
Total		1316	100.00
KP-2-91-III-2	Alatacythere aff. A. serrata	74	5.61
KP-2-91-III-2	Amphicytherura curta	68	5.15
KP-2-91-III-2	Antibythocypris crassa	4	0.30
KP-2-91-III-2	Antibythocypris fabaformis	3	0.23
KP-2-91-III-2	Antibythocypris gooberi	16	1.21
KP-2-91-III-2	Antibythocypris minuta	4	0.30
KP-2-91-III-2	Antibythocypris pataulensis	1	0.08
KP-2-91-III-2	Anticythereis sp. 14	4	0.30
KP-2-91-III-2	Anticythereis sp. 17	1	0.08
KP-2-91-III-2	Anticythereis sp. 4	1	0.08
KP-2-91-III-2	Anticythereis sp. 4	1	0.08
KP-2-91-III-2	Anticythereis copelandi	1	0.08
KP-2-91-III-2	Ascetoleberis hazardi	21	1.59
KP-2-91-III-2	Aversovalva fossata s.l.	3	0.23
KP-2-91-III-2	Brachycythere foraminosa s.l.	32	2.42
KP-2-91-III-2	Brachycythere ledaforma	29	2.20
KP-2-91-III-2	Brachycythere ovata	222	16.82
KP-2-91-III-2	Brachycythere ovata w/ ridge	8	0.61
KP-2-91-III-2	Brachycythere rhomboidalis	99	7.50
KP-2-91-III-2	Bairdoppilata magna	186	14.09
KP-2-91-III-2	Bairdia n. sp. 1	3	0.23
KP-2-91-III-2	Curfsina communis	123	9.32
KP-2-91-III-2	Cytherella	200	15.15
KP-2-91-III-2	Cytherelloidea bicosta s.l.	27	2.05
KP-2-91-III-2	Cytheropteron n. sp. A	2	0.15
KP-2-91-III-2	Cytheropteron navarroense	2	0.15
KP-2-91-III-2	Escharacytheridea pinochii	70	5.30
KP-2-91-III-2	Eucytherura aff. E. reticulata	2	0.15
KP-2-91-III-2	Fissocarinocythere huntensis	9	0.68
KP-2-91-III-2	Haplocytheridea bruceclarki	11	0.83
KP-2-91-III-2	Krithe whitecliffsensis	18	1.36
KP-2-91-III-2	Limburgina foresterae	15	1.14
KP-2-91-III-2	Loxoconcha clinocosta	9	0.68
KP-2-91-III-2	Loxoconcha erecticosta	2	0.15
KP-2-91-III-2	Loxoconcha striata	2	0.15
KP-2-91-III-2	Orthonotacythere hannai	6	0.45
KP-2-91-III-2	Opimocythere aff. hazeli	9	0.68

Sample no.	Species	Valves	Percentage
KP-2-91-III-2	"Planileberis" cf. "P." costatana	7	0.53
KP-2-91-III-2	Platycosta lixula	10	0.76
KP-2-91-III-2	Polylophus asper	2	0.15
KP-2-91-III-2	Pterygocythere saratogana	4	0.30
KP-2-91-III-2	Soudanella paralle	1	0.08
KP-2-91-III-2	Veenia parallelopora	7	0.53
KP-2-91-III-2	Veenia adkinsi	1	0.08
KP-2-91-III-2	Xestoleberis opina	63	4.77
Total		1320	100.00
KP-2-91-III-3	Alatacythere aff. A. serrata	4	0.41
KP-2-91-III-3	Amphicytherura curta	41	4.20
KP-2-91-III-3	Antibythocypris crassa	14	1.43
KP-2-91-III-3	Antibythocypris fabaformis	5	0.51
KP-2-91-III-3	Antibythocypris gooberi	13	1.33
KP-2-91-III-3	Antibythocypris johnsoni	1	0.10
KP-2-91-III-3	Antibythocypris minuta	8	0.82
KP-2-91-III-3	Antibythocypris multilira	3	0.31
KP-2-91-III-3	Anticythereis sp. 14	2	0.20
KP-2-91-III-3	Anticythereis cf. 38	1	0.10
KP-2-91-III-3	Anticythereis sp. 4	1	0.10
KP-2-91-III-3	Anticythereis priddyi	1	0.10
KP-2-91-III-3	Anticythereis sq 1	1	0.10
KP-2-91-III-3	Argilloecia n sp 2	2	0.20
KP-2-91-III-3	Aversovalva fossata s.l.	1	0.10
KP-2-91-III-3	Brachycythere foraminosa s.l.	16	1.64
KP-2-91-III-3	Brachycythere ledaforma	3	0.31
KP-2-91-III-3	Brachycythere ovata	95	9.73
KP-2-91-III-3	Brachycythere ovata w/ ridge	32	3.28
KP-2-91-III-3	Brachycythere rhomboidalis	80	8.20
KP-2-91-III-3	Bairdoppilata magna	212	21.72
KP-2-91-III-3	Bairdia w/ denticulation	3	0.31
KP-2-91-III-3	Bythocypris windhami	3	0.31
KP-2-91-III-3	Curfsina communis	39	4.00
KP-2-91-III-3	Cytherella	163	16.70
KP-2-91-III-3	Cytherelloidea bicosta s.l.	38	3.89
KP-2-91-III-3	Cytheropteron castorensis	1	0.10
KP-2-91-III-3	Cytheropteron coryelli	1	0.10
KP-2-91-III-3	Cytheropteron n. sp. A	2	0.20
KP-2-91-III-3	Escharacytheridea pinochii	13	1.33
KP-2-91-III-3	Eucythere sohli	2	0.20
KP-2-91-III-3	Eucytherura aff. E. reticulata	1	0.10
KP-2-91-III-3	Eucytherura reticulata	2	0.20
KP-2-91-III-3	Fissocarinocythere huntensis	9	0.92
KP-2-91-III-3	Haplocytheridea bruceclarki	20	2.05
KP-2-91-III-3	Haplocytheridea n. sp. A	6	0.61
KP-2-91-III-3	Limburgina foresterae	3	0.31
KP-2-91-III-3	Loxoconcha clinocosta	15	1.54
KP-2-91-III-3	Loxoconcha erecticosta	10	1.02
KP-2-91-III-3	Loxoconcha striata	2	0.20
KP-2-91-III-3	Orthonotacythere hannai	3	0.31

Sample no.	Species	Valves	Percentage
KP-2-91-III-3	Opimocythere aff. hazeli	21	2.15
KP-2-91-III-3	Paracypris sp. 3	1	0.10
KP-2-91-III-3	Pectocythere hughesi	8	0.82
KP-2-91-III-3	"Planileberis" cf. "P." costatana	5	0.51
KP-2-91-III-3	Platycosta lixula	8	0.82
KP-2-91-III-3	Pterygocythere saratogana	1	0.10
KP-2-91-III-3	Soudanella paralle	1	0.10
KP-2-91-III-3	Xestoleberis n. sp. 3	2	0.20
KP-2-91-III-3	Xestoleberis opina	57	5.84
Total		976	100.00
KP-2-91-III-5	Amphicytherura curta	3	2.19
KP-2-91-III-5	Antibythocypris crassa	2	1.46
KP-2-91-III-5	Antibythocypris gooberi	4	2.92
KP-2-91-III-5	Antibythocypris minuta	5	3.65
KP-2-91-III-5	Brachycythere foraminosa s.l.	2	1.46
KP-2-91-III-5	Brachycythere ovata w/	27	19.71
KP-2-91-III-5	Brachycythere rhomboidalis	3	2.19
KP-2-91-III-5	Bairdoppilata magna	36	26.28
KP-2-91-III-5	Bythocypris windhami	1	0.73
KP-2-91-III-5	Curfsina communis	4	2.92
KP-2-91-III-5	Cytherella	15	10.95
KP-2-91-III-5	Cytherelloidea truncata lowndesensis	8	5.84
KP-2-91-III-5	Cytheropteron castorensis	2	1.46
KP-2-91-III-5	Cytheropteron TYPE B	2	1.46
KP-2-91-III-5	Escharacytheridea pinochii	2	1.46
KP-2-91-III-5	Haplocytheridea bruceclarki	1	0.73
KP-2-91-III-5	Haplocytheridea n. sp. A	4	2.92
KP-2-91-III-5	Loxoconcha clinocosta	6	4.38
KP-2-91-III-5	Opimocythere aff. hazeli	5	3.65
KP-2-91-III-5	Opimocythere hazeli	1	0.73
KP-2-91-III-5	"Planileberis" cf. "P." costatana	2	1.46
KP-2-91-III-5	Xestoleberis opina	2	1.46
Total		137	100.00
KP-2-91-III-6	Barren		
KP-2-91-III-7	Amphicytherura curta	3	1.11
KP-2-91-III-7	Antibythocypris crassa (J)	2	0.74
KP-2-91-III-7	Antibythocypris minuta	1	0.37
KP-2-91-III-7	Brachycythere ovata w/ ridge	8	2.95
KP-2-91-III-7	Brachycythere plena	22	8.12
KP-2-91-III-7	Brachycythere rhomboidalis	2	0.74
KP-2-91-III-7	Bairdoppilata magna	40	14.76
KP-2-91-III-7	Bairdia n. sp. 1	5	1.85
KP-2-91-III-7	Bairdia n. sp. 2	26	9.59
KP-2-91-III-7	Curfsina communis	2	0.74
KP-2-91-III-7	Cytherella	55	20.30
KP-2-91-III-7	Cytherelloidea truncata lowndesensis	9	3.32
KP-2-91-III-7	Eucytherura aff. E. reticulata	1	0.37
KP-2-91-III-7	Eucytherura reticulata	3	1.11

Sample no.	Species	Valves	Percentage
KP-2-91-III-7	Haplocytheridea n. sp. B	1	0.37
KP-2-91-III-7	Hermanites cf. H. plusculmensis	9	3.32
KP-2-91-III-7	Limburgina foresterae	1	0.37
KP-2-91-III-7	Loxoconcha aff. clinocosta	8	2.95
KP-2-91-III-7	Loxoconcha nuda	8	2.95
KP-2-91-III-7	Opimocythere aff. hazeli	6	2.21
KP-2-91-III-7	Opimocythere hazeli	25	9.23
KP-2-91-III-7	Paracypris perapiculata	14	5.17
KP-2-91-III-7	Paracypris sp. 3	12	4.43
KP-2-91-III-7	Pectocythere hughesi	5	1.85
KP-2-91-III-7	Phractocytheridea ruginosa	2	0.74
KP-2-91-III-7	"Planileberis" cf. "P." costatana	1	0.37
Total		271	100.00
KP-2-91-III-8	Bairdoppilata magna	3	25.00
KP-2-91-III-8	Bairdia n. sp. 2	2	16.67
KP-2-91-III-8	Brachycythere plena	2	16.67
KP-2-91-III-8	Cytherella	2	16.67
KP-2-91-III-8	Opimocythere hazeli	3	25.00
Total		12	100.00
KP-2-91-III-9	Bairdoppilata magna	6	33.33
KP-2-91-III-9	Bairdia nsp2	4	22.22
KP-2-91-III-9	Brachycythere plena	1	5.56
KP-2-91-III-9	Cytherella	1	5.56
KP-2-91-III-9	Opimocythere hazeli	6	33.33
Total		18	100.00
KP-93-III-1	Alatacythere aff. A. serrata	2	1.40
KP-93-III-1	Amphicytherura curta	1	0.70
KP-93-III-1	Antibythocypris gooberi	4	2.80
KP-93-III-1	Ascetoleberis hazardi	1	0.70
KP-93-III-1	Brachycythere ledaforma	6	4.20
KP-93-III-1	Brachycythere ovata	11	7.69
KP-93-III-1	Brachycythere rhomboidalis	3	2.10
KP-93-III-1	Bairdoppilata magna	23	16.08
KP-93-III-1	Bythocypris windhami	4	2.80
KP-93-III-1	Curfsina communis	1	0.70
KP-93-III-1	Cytherella	46	32.17
KP-93-III-1	Cytherelloidea aff. austin	1	0.70
KP-93-III-1	Cytherelloidea bicosta	2	1.40
KP-93-III-1	Cytherelloidea crafti	1	0.70
KP-93-III-1	Cytheropteron crafti	1	0.70
KP-93-III-1	Fissocarinocythere huntensis	2	1.40
KP-93-III-1	Haplocytheridea bruceclarki	8	5.59
KP-93-III-1	Krithe whitecliffsensis	6	4.20
KP-93-III-1	Macrocypris n. sp. 1	2	1.40
KP-93-III-1	Paracypris sp. 3	2	1.40
KP-93-III-1	Platycosta lixula	2	1.40
KP-93-III-1	Pterygocythere saratogana	5	3.50
KP-93-III-1	Xestoleberis n. sp. 3	1	0.70

Sample no.	Species	Valves	Percentage
KP-93-III-1	Xestoleberis opina	8	5.59
Total		143	100.00
KP-93-III-10	Amphicytherura curta	2	2.60
KP-93-III-10	Antibythocypris crassa	2	2.60
KP-93-III-10	Antibythocypris pataulensis	1	1.30
KP-93-III-10	Antibythocypris minuta	5	6.49
KP-93-III-10	Brachycythere ovata	5	6.49
KP-93-III-10	Brachycythere rhomboidalis	5	6.49
KP-93-III-10	Bairdoppilata magna	30	38.96
KP-93-III-10	Bythocypris windhami	2	2.60
KP-93-III-10	Curfsina communis	3	3.90
KP-93-III-10	Cytherella	13	16.88
KP-93-III-10	Cytherelloidea aff. austinensis	2	2.60
KP-93-III-10	Cytherelloidea bicosta	4	5.19
KP-93-III-10	Haplocytheridea bruceclarki	1	1.30
KP-93-III-10	Macrocypris n. sp. 4	2	2.60
Total		77	100.00
KP-93-III-2	Alatacythere aff. A. serrata	9	2.75
KP-93-III-2	Antibythocypris gooberi	11	3.36
KP-93-III-2	Antibythocypris minuta	1	0.31
KP-93-III-2	Ascetoleberis hazardi	4	1.22
KP-93-III-2	Brachycythere foraminosa s.l.	4	1.22
KP-93-III-2	Brachycythere ledaforma	10	3.06
KP-93-III-2	Brachycythere ovata	15	4.59
KP-93-III-2	Brachycythere ovata w/	2	0.61
KP-93-III-2	Brachycythere rhomboidalis	14	4.28
KP-93-III-2	Bairdoppilata magna	12	3.67
KP-93-III-2	Bythocypris windhami	1	0.31
KP-93-III-2	Curfsina communis	10	3.06
KP-93-III-2	Cytherella	128	39.14
KP-93-III-2	Cytherelloidea bicosta	24	7.34
KP-93-III-2	Cytheropteron coryelli	1	0.31
KP-93-III-2	Eucythere sohli	1	0.31
KP-93-III-2	Eucytherura aff. E. reticulata	1	0.31
KP-93-III-2	Fissocarinocythere huntensis	12	3.67
KP-93-III-2	Haplocytheridea bruceclarki	9	2.75
KP-93-III-2	Krithe whitecliffsensis	11	3.36
KP-93-III-2	Macrocypris n. sp. 1	2	0.61
KP-93-III-2	"Monoceratina" aff. umbonata	1	0.31
KP-93-III-2	"Monoceratina" nsp B	2	0.61
KP-93-III-2	"Monoceratina" nsp C	2	0.61
KP-93-III-2	"Monoceratina" prothroensis	2	0.61
KP-93-III-2	Paracypris sp. 2	2	0.61
KP-93-III-2	Paracypris sp. 3	2	0.61
KP-93-III-2	"Planileberis" cf. "P." costatana	3	0.92
KP-93-III-2	Platycosta lixula	4	1.22
KP-93-III-2	Pterygocythere saratogana	15	4.59
KP-93-III-2	Veenia parallelopora	3	0.92
KP-93-III-2	Xestoleberis opina	5	1.53

Sample no.	Species	Valves	Percentage
KP-93-III-2	Xestoleberis seminulata	4	1.22
Total		327	100.00
KP-93-III-3	Alatacythere aff. A. serrata	5	1.81
KP-93-III-3	Amphicytherura curta	1	0.36
KP-93-III-3	Antibythocypris gooberi	3	1.09
KP-93-III-3	Ascetoleberis hazardi	6	2.17
KP-93-III-3	Brachycythere foraminosa s.l.	6	2.17
KP-93-III-3	Brachycythere ledaforma	14	5.07
KP-93-III-3	Brachycythere ovata	15	5.43
KP-93-III-3	Brachycythere ovata w/	7	2.54
KP-93-III-3	Brachycythere rhomboidalis	6	2.17
KP-93-III-3	Bairdoppilata magna	4	1.45
KP-93-III-3	Bythocypris windhami	2	0.72
KP-93-III-3	Curfsina communis	3	1.09
KP-93-III-3	Cytherella	103	37.32
KP-93-III-3	Cytherelloidea bicosta s.l.	22	7.97
KP-93-III-3	Cytheropteron coryelli	2	0.72
KP-93-III-3	Fissocarinocythere huntensis	8	2.90
KP-93-III-3	Haplocytheridea bruceclarki	9	3.26
KP-93-III-3	Krithe whitecliffsensis	10	3.62
KP-93-III-3	Macrocypris n. sp. 1	6	2.17
KP-93-III-3	"Monoceratina" aff. umbonata	1	0.36
KP-93-III-3	"Monoceratina" nsp C	2	0.72
KP-93-III-3	Paracypris sp. 3	8	2.90
KP-93-III-3	Pterygocythere saratogana	20	7.25
KP-93-III-3	Veenia parallelopora	6	2.17
KP-93-III-3	Xestoleberis s	7	2.54
Total		276	100.00
KP-93-III-4	Brachycythere foraminosa s.l.	2	9.52
KP-93-III-4	Brachycythere ovata	1	4.76
KP-93-III-4	Bairdoppilata magna	1	4.76
KP-93-III-4	Bairdia n. sp. 2	2	9.52
KP-93-III-4	Curfsina communis	3	14.29
KP-93-III-4	Cytherella	5	23.81
KP-93-III-4	Cytherelloidea spiralia	1	4.76
KP-93-III-4	Cytherelloidea bicosta s.l.	2	9.52
KP-93-III-4	Macrocypris n. sp. 4	2	9.52
KP-93-III-4	Orthonotacythere hannai	1	4.76
KP-93-III-4	Xestoleberis opina	1	4.76
Total		21	100.00
KP-93-III-5	Amphicytherura curta	3	2.22
KP-93-III-5	Antibythocypris minuta	2	1.48
KP-93-III-5	Anticythereis copelandi	1	0.74
KP-93-III-5	Anticythereis sp. 15	2	1.48
KP-93-III-5	Brachycythere ledaforma	1	0.74
KP-93-III-5	Brachycythere ovata	13	9.63
KP-93-III-5	Brachycythere ovata w/	11	8.15
KP-93-III-5	Brachycythere rhomboidalis	2	1.48

Sample no.	Species	Valves	Percentage
KP-93-III-5	Bairdoppilata magna	67	49.63
KP-93-III-5	Bairdia n. sp. 2	1	0.74
KP-93-III-5	Bythocypris windhami	6	4.44
KP-93-III-5	Cytherella	14	10.37
KP-93-III-5	Cytherelloidea bicosta s.l.	3	2.22
KP-93-III-5	Haplocytheridea everetti	4	2.96
KP-93-III-5	Haplocytheridea bruceclarki	2	1.48
KP-93-III-5	"Planileberis" cf. "P." costatana	2	1.48
KP-93-III-5	Platycosta lixula	1	0.74
Total		135	100.00
KP-93-III-6	Amphicytherura curta	11	4.31
KP-93-III-6	Antibythocypris crassa	6	2.35
KP-93-III-6	Antibythocypris gooberi	9	3.53
KP-93-III-6	Antibythocypris minuta	9	3.53
KP-93-III-6	Anticythereis sp. 4	2	0.78
KP-93-III-6	Anticythereis cf. A. sp. 4	2	0.78
KP-93-III-6	Ascetoleberis hazardi	1	0.39
KP-93-III-6	Brachycythere foraminosa s.l.	15	5.88
KP-93-III-6	Brachycythere ovata	37	14.51
KP-93-III-6	Brachycythere rhomboidalis	15	5.88
KP-93-III-6	Bairdoppilata magna	45	17.65
KP-93-III-6	Bairdia n. sp. 2	8	3.14
KP-93-III-6	Bythocypris windhami	8	3.14
KP-93-III-6	Curfsina communis	13	5.10
KP-93-III-6	Cytherella	45	17.65
KP-93-III-6	Cytherelloidea bicosta s.l.	5	1.96
KP-93-III-6	Cytheropteron cf. TYPE A	1	0.39
KP-93-III-6	genus?	1	0.39
KP-93-III-6	Haplocytheridea bruceclarki	2	0.78
KP-93-III-6	Haplocytheridea everetti	11	4.31
KP-93-III-6	Limburgina foresterae	2	0.78
KP-93-III-6	Paracypris sp. 3	2	0.78
KP-93-III-6	Pterygocythere saratogana	1	0.39
KP-93-III-6	Veenia adkinsi	2	0.78
KP-93-III-6	Xestoleberis n. sp. 3	1	0.39
KP-93-III-6	Xestoleberis seminulata	1	0.39
Total		255	100.00
KP-93-III-7	Amphicytherura curta	2	6.25
KP-93-III-7	Antibythocypris crassa	1	3.13
KP-93-III-7	Antibythocypris fabaformis	1	3.13
KP-93-III-7	Antibythocypris minuta	3	9.38
KP-93-III-7	Bairidia magnana	3	9.38
KP-93-III-7	Brachycythere foraminosa s.l.	2	6.25
KP-93-III-7	Curfsina communis	6	18.75
KP-93-III-7	Cytherella	11	34.38
KP-93-III-7	Cytherelloidea bicosta	1	3.13
KP-93-III-7	Krithe whitecliffsensis	2	6.25
Total		32	100.00

Sample no.	Species	Valves	Percentage
KP-93-III-8	Barren		
KP-93-III-9	Brachycythere foraminosa s.l.	2	4.35
KP-93-III-9	Brachycythere ovata	7	15.22
KP-93-III-9	Brachycythere ovata w/	1	2.17
KP-93-III-9	Brachycythere rhomboidalis	1	2.17
KP-93-III-9	Bairdoppilata magna	15	32.61
KP-93-III-9	Bythocypris windhami	4	8.70
KP-93-III-9	Curfsina communis	2	4.35
KP-93-III-9	Cytherella	12	26.09
KP-93-III-9	Haplocytheridea everetti	2	4.35
Total		46	100.00
KP-93-V-1	Alatacythere aff. A. serrata	9	3.93
KP-93-V-1	Ascetoleberis hazardi	6	2.62
KP-93-V-1	Brachycythere foraminosa	5	2.18
KP-93-V-1	Brachycythere ledaforma	6	2.62
KP-93-V-1	Brachycythere ovata	23	10.04
KP-93-V-1	Brachycythere rhomboidalis	19	8.30
KP-93-V-1	Bythocypris windhami	8	3.49
KP-93-V-1	Curfsina communis	14	6.11
KP-93-V-1	Cytherella	42	18.34
KP-93-V-1	Cytheropteron navarroense	7	3.06
KP-93-V-1	Escharacytheridea micropunctata	12	5.24
KP-93-V-1	Fissocarinocythere huntensis	5	2.18
KP-93-V-1	Haplocytheridea bruceclarki	41	17.90
KP-93-V-1	Krithe whitecliffsensis	20	8.73
KP-93-V-1	Loxoconcha striata	2	0.87
KP-93-V-1	"Monoceratina" aff. umbonata	1	0.44
KP-93-V-1	Pterygocythere saratogana	4	1.75
KP-93-V-1	Veenia parallelopora	5	2.18
Total		229	100.00
KP-93-V-2	Alatacythere aff. A. serrata	13	3.62
KP-93-V-2	Ascetoleberis hazardi	18	5.01
KP-93-V-2	Brachycythere foraminosa s.l.	16	4.46
KP-93-V-2	Brachycythere ledaforma	15	4.18
KP-93-V-2	Brachycythere ovata	11	3.06
KP-93-V-2	Brachycythere ovata w/	2	0.56
KP-93-V-2	Brachycythere rhomboidalis	48	13.37
KP-93-V-2	Bythocypris windhami	4	1.11
KP-93-V-2	Curfsina communis	14	3.90
KP-93-V-2	Cytherella	74	20.61
KP-93-V-2	Cytheropteron navarroense	18	5.01
KP-93-V-2	Escharacytheridea micropunctata	3	0.84
KP-93-V-2	Escharacytheridea pinochii	5	1.39
KP-93-V-2	Fissocarinocythere huntensis	23	6.41
KP-93-V-2	Haplocytheridea bruceclarki	48	13.37
KP-93-V-2	Krithe whitecliffsensis	28	7.80
KP-93-V-2	Loxoconcha striata	6	1.67
KP-93-V-2	Paracypris sp. 1	2	0.56

Sample no.	Species	Valves	Percentage
KP-93-V-2	"Monoceratina" aff. umbonata	2	0.56
KP-93-V-2	Pterygocythere saratogana	7	1.95
KP-93-V-2	Xestoleberis opina	2	0.56
Total		359	100.00
KP-93-V-3	Antibythocypris crassa	1	8.33
KP-93-V-3	Brachycythere ovata	1	8.33
KP-93-V-3	Brachycythere ovata w/	2	16.67
KP-93-V-3	Bairdoppilata magna	7	58.33
KP-93-V-3	Haplocytheridea everetti	1	8.33
Total		12	100.00
KP-93-V-4	Antibythocypris crassa	3	6.00
KP-93-V-4	Antibythocypris minuta	1	2.00
KP-93-V-4	Antibythocypris pataulensis	1	2.00
KP-93-V-4	Brachycythere foraminosa	2	4.00
KP-93-V-4	Brachycythere ovata	2	4.00
KP-93-V-4	Brachycythere ovata w/	2	4.00
KP-93-V-4	Brachycythere rhomboidalis	1	2.00
KP-93-V-4	Bairdoppilata magna	25	50.00
KP-93-V-4	Curfsina communis	2	4.00
KP-93-V-4	Cytherella	10	20.00
KP-93-V-4	Veenia parallelopora	1	2.00
Total		50	100.00
KP-93-V-5	Antibythocypris crassa	6	9.23
KP-93-V-5	Antibythocypris minuta	1	1.54
KP-93-V-5	Brachycythere foraminosa	3	4.62
KP-93-V-5	Brachycythere ovata	14	21.54
KP-93-V-5	Brachycythere ovata w/	8	12.31
KP-93-V-5	Bairdoppilata magna	11	16.92
KP-93-V-5	Curfsina communis	2	3.08
KP-93-V-5	Cytherella	6	9.23
KP-93-V-5	Haplocytheridea everetti	10	15.38
KP-93-V-5	Veenia parallelopora	1	1.54
KP-93-V-5	Veenia arachoides	3	4.62
Total		65	100.00
KP-93-V-6	Antibythocypris crassa	1	0.57
KP-93-V-6	Antibythocypris minuta	1	0.57
KP-93-V-6	Brachycythere ovata	2	1.15
KP-93-V-6	Brachycythere ovata w/ ridge	6	3.45
KP-93-V-6	Brachycythere plena	20	11.49
KP-93-V-6	Bairdoppilata magna	35	20.11
KP-93-V-6	Curfsina communis	1	0.57
KP-93-V-6	Cytherella	66	37.93
KP-93-V-6	Hazelina n. sp. A	2	1.15
KP-93-V-6	Pectocythere hughesi	2	1.15
KP-93-V-6	Phacorhabdotus aff. P. formosus	38	21.84
Total		174	100.00

Sample no.	Species	Valves	Percentage
KP-93-V-7	Alatacythere lemincata	1	0.55
KP-93-V-7	Antibythocypris crassa (reworked)	4	2.21
KP-93-V-7	Antibythocypris gooberi	3	1.66
KP-93-V-7	Antibythocypris minuta (rework)	2	1.10
KP-93-V-7	Antibythocypris multilira (surv)	2	1.10
KP-93-V-7	Antibythocypris phaseolites(rework)	1	0.55
KP-93-V-7	Argilloecia n sp 3	2	1.10
KP-93-V-7	Brachycythere foraminosa(surv)	1	0.55
KP-93-V-7	Brachycythere ovata w/	32	17.68
KP-93-V-7	Brachycythere plena	6	3.31
KP-93-V-7	Brachycythere rhomboidalis	1	0.55
KP-93-V-7	Bairdoppilata magna	45	24.86
KP-93-V-7	Curfsina communis	4	2.21
KP-93-V-7	Cytherella	37	20.44
KP-93-V-7	Haplocytheridea everetti (rework)	1	0.55
KP-93-V-7	Krithe n. sp. A	5	2.76
KP-93-V-7	Limburgina foresterae	1	0.55
KP-93-V-7	Loxoconcha corrugata	2	1.10
KP-93-V-7	Loxoconcha n. sp. D (Tertiary)	1	0.55
KP-93-V-7	"Monoceratina" n. sp. G	1	0.55
KP-93-V-7	Paracypris perapiculata	1	0.55
KP-93-V-7	Phacorhabdotus aff. P. formosus	23	12.71
KP-93-V-7	Phacorhabdotus formosus	1	0.55
KP-93-V-7	Xestoleberis seminulata	4	2.21
Total		181	100.00

APPENDIX V

LETTERS OF PERMISSION

LOUISIANA STATE UNIVERSITY
AND AGRICULTURAL AND MECHANICAL COLLEGE
Department of Geology and Geophysics

July 11, 1994

Dr. Don C. Steinker, Managing Editor
JOURNAL OF PALEONTOLOGY
Department of Geology
Bowling Green State Univeristy
Bowling Green, Ohio 43403

Dear Dr. Steinker:

Regarding the recently published paper in the Journal of Paleontology, I would like to request permission to use the paper as one of the chapters of my dissertation. The paper is

Kasana Pitakpaivan and Joseph E. Hazel, 1994, Ostracodes and chronostratigraphic position of the Upper Cretaceous Arkadelphia Formation of Arkansas, Journal of Paleontology, v. 68, no. 1, pp. 111-122.

It is required by Louisiana State University that I submit written permission from the Journal of Paleontology with the copy of my dissertation. The paper will have to be reformatted according to the guidelines of the Graduate School. The changes include 1) a different font and margin width, and 2) a placement of tables and figures will be scattered throughout the text. The content in text, figures, tables and plates will be identical to what appeared in the journal.

Please find a form at the bottom part of this letter, if you wish to use it for convenience. I greatly appreciate your assistance.

Sincerely,

K. Pitakpaivan

Kasana Pitakpaivan

Permission is granted to use the paper titled "Ostracodes and chronostratigraphic position of the Upper Cretaceous Arkadelphia Formation of Arkansas" as a chapter in the dissertation entitled "Ostracoda of the latest Cretaceous and earliest Tertiary of the Gulf Coastal Plain: Biostratigraphy, Paleoenvironments and Systematics".

27 August 1994 (date) Thomas W. Henry (signature)
Secretary, The Paleontological Society

ELSEVIER
SCIENCE

Amsterdam Publishing Division

Sara Burgerhartstraat 25
1055 KV Amsterdam
The Netherlands

P.O. Box 521
1000 AM Amsterdam
The Netherlands

Tel (+31) 20 5862 833
Fax (+31) 20 5862 722

Lousiana State University
and Agricultural and Mechanical College
Baton Rouge, Louisiana
70803-4101
U.S.A.
Attn. Kasana Pitakpaivan

Direct Line: (020) 5862 833

Amsterdam, 19 July 1994

Dear Dr.Pitakpaivan,

Thank you for your recent letter in which you request permission to reproduce the following articles in your **dissertation.**

Re: Pseudomorphs of impact spherules from a Cretaceous-Tertiary boundary section at Shell Creek, Alabama by K. Pitakpaivan et al in Earth and Planetary Scienc Letters Vol. 124, no. 1-4, pp. 49-56

We are pleased to grant you permission to reproduce this material, provided that you give full acknowledgement to the original source of publication, and that your work is not distributed commercially.

Yours sincerely,
ELSEVIER SCIENCE B.V.
Amsterdam Publishing Division

Jan van den Heuvel
Rights & Permissions

VITA

Kasana Pitakpaivan Soonthornsaratul, daughter of Kaset and Piabsri Pitakpaivan, was born in Bangkok, Thailand on July 27, 1962. Her interest in geology led to the degree of Bachelor of Science in Geology from Chulalongkorn University in May 1984. In September 1984, she began work at the Geological Survey Division, Department of Mineral Resources, Bangkok, Thailand.

In August 1986, she was granted a leave of absence from the DMR to study at Texas A&I Univeristy, Kingsville, Texas, where she received her Master of Science in Geology in December 1988. In January 1989, she began her work at Louisiana State University under the direction of Dr. Joseph E. Hazel. She is married to Chekchanok Soonthornsaratul.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Kasana Pitakpaivan

Major Field: Geology

Title of Dissertation: Ostracoda of the Latest Cretaceous and Earliest Tertiary of the Gulf Coastal Plain: Biostratigraphy, Paleoenvironments, and Systematics

Approved:

Joseph E. Hazel
Major Professor and Chairman

John M. Larkin
Dean of the Graduate School

EXAMINING COMMITTEE:

Chad McCabe

Gary Byerly

Lui-Heung Chan

Richard H. Kesel

Barun K. Sen Gupta

Date of Examination:

September, 2, 1994